**MINISTRY OF EDUCATION OF RUSSIAN FEDERATION**

**TOMSK POLYTECHNIC UNIVERSITY**

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# MINISTRY OF EDUCATION OF RUSSIAN FEDERATION

# TOMSK POLYTECHNIC UNIVERSITY

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# 1. INTRODUCTION

Production efficiency, its technical progress, quality of let out production in many respects depend on outstripping development of manufacture of the new equipment, machines, machine tools and devices, from the introduction of methods of the technical and economic analysis ensuring the solution to technical questions and economic efficiency of technological and design development.

The purpose of this Diploma Paper is to outline the development of technological process and designing of the attachment for the milling of key slot 8H9 (clamping on V-block with a pneumonic drive). It enables to receive the necessary skills for the development of part manufacturing technology and will improve the theoretical knowledge of the discipline: "Technology of Mechanical Engineering".

## 2. DEFINITION of a MANUFACTURING TYPE

The annual program of products N = 10000 pieces.
The real annual fund of an operating time of the equipment is determined from the recommendations for the table 4 [4, page 23] for work in 2 shifts: $F_r$=4015 h.
We determine a step of details release (manufacturing):

$$t_m = \frac{F_r \cdot 60}{N} = \frac{4015 \cdot 60}{10000} = 24.9\left(\frac{\min}{piece}\right),$$

Where Fr - the real annual fund of an operating time of the equipment, hour.
The data on existing (similar) factory technological process or on integrated fixing of operations are given in tab. 1.

Table 1. Duration of operations of the existing factory technological process

| № of operation | The name of operation | $T_f$, min. |
|---|---|---|
| 1 | Turret-lathe | 1.96 |
| 2 | Turret-lathe | 0.45 |
| 3 | Vertical - drilling | 0.02 |
| 4 | Round grinding | 0.32 |
| 5 | Flat grinding | 0.15 |
| 6 | Inner grinding | 3.15 |
| | Total floor-to-floor time $\sum T_f$ = 5.93 min. | |

Quantity of operations n=6.
Total floor-to-floor time (piece-time) of all operations:

$$\sum T_f = 5.93 \text{ minutes.}$$

We shall define (determine) average floor-to-floor time according to the formula:

$$T_{f\,av} = \sum T_f /n = 5.93/6 = 0.988 \text{ min.}$$

We shall define factor of manufacturing type according to the formula:

$$k_m = t_m / T_{f\,av} = 24.9/0.988 = 25.2.$$

Since $20 \le k_m \le 40$, the type of manufacture is a small-scale manufacture.

## 2.1. Calculation of parts quantity in a set (batch size)

The annual program of release $N$ = 10000 pieces; $T_{f\,av}$ =0.988 min.
Periodicity of start - release of products $a$ = 5 days.
Number of working days in one year $F$ = 240 days.
We shall define settlement quantity of parts (details) in a set according to the formula:

$$n = N \times a \,/\, F = 10000 \times 5/240 = 208 \text{ pieces},$$

Where $a$ is the quantity of storage days. For small and inexpensive details it is 5…10 days. But more storage days means more unfinished manufacturing, which is why we accept 5 days.
The settlement number of shifts for processing of parts set on a site (shop) is defined according to the formula:

$$c = (T_{f\,av} \times n)/\,(480 \times 0.8) = (0.988 \times 208)/\,(480 \times 0.8) = 0.53.$$

The accepted number of shifts for processing of details set on a site: $c_{ac}$=1 shift.
The accepted number of details in a set is:

$$n_{ac} = c_{ac} \times 480 \times 0.8/\, T_{f\,av} = 1 \cdot 480 \times 0.8/0.988 = 388 \text{ pieces} \approx 400 \text{ pieces}.$$

# 3. TECHNOLOGICAL PROCESS DESIGN of SLEEVE MACHINING

## 3.1. ANALYSIS of SLEEVE MACHINING ADAPTABILITY

The part (blank) is made of steel 40X (0.40 % of carbon C, Cr – 1%, sulfur S < 0.09 %; phosphorus P < 0.035 %), therefore blank (production) can be obtained in different ways and shapes: by hot or cold rolling, stamping (punching), forging, casting; rod. The part has large difference of diameters, which not allow using rod as a blank and thus the use of casting or punching techniques for mass and business lot production. But punching technique in steel production is more preferable (in order to avoid cavities in the body of the blank).The material structure is more uniform and that is why we would use forged or stamped blank.

The preliminary processing of external surfaces is made on a lathe machine tool, a key slot 8H9 on the conical surface – on a vertical-milling machine tool with use of a special attachment with clamping on V-block with a pneumonic drive, the machining of the thread M20-8g – by a die on the lathe.

The conical surface with conicity C=1:10 should be preliminary machined on a DNC lathe machine tool.

The final processing should be made on grinding machine tools, as the sizes Ø30g6 and Ø40t7 should be executed with the close tolerance (with the sixth and seventh grade of tolerance) and with a small roughness of surfaces (Ra≤0.8 and

1.25 microns). The conical surface with conicity C=1:10 should be made on grinding machine tool.

The end faces of the part should be machined by turning, since the length of the shaft 220h14 (note: high accuracy is not required).

The shape of the part is convenient for manufacturing. The processing of the external surfaces should be machined in rough and semi-finish operations. It is also necessary to use centre holes in order to obtain a higher accuracy of the radial palpitation surfaces Ø30g6 , Ø40t7, the conical surface with conicity C=1:10 (tolerance is 0.02 mm) and easy to clamp the shaft. The shaft is machined between two centers; thereafter centre holes are drilled in the first and second operations.

The configuration of the part provides easy removal of chips. This type of a blank allows producing the part by processing it in the universal self-centering 3-jaw chuck for the rough (draft) operations and in collet chuck or on self-centering mandrel with expansion bushing - in finishing operations. The application of exact attachments at final processing is necessary in connection with the close-off tolerance (0.05 mm) of radial palpation of the external cylindrical surface Ø30g6 and 40t7 relative to conical surface.

The application of thermal operation requires. Material (steel 40X) allows to carry out quenching with the specified hardness (it is better to use steel 40X for reduction of required speed of cooling and the possibility of warp of the part). Final processing of surfaces with the exact sizes (Ø30g6, 40t7 and the conical surface C=1:10) should be carried out after thermal operation for the elimination of the possibility of warp of the part. Thus for the final processing, sufficient stock (allowance) should be left in the point of view of a part warping.

## 3.2. STEPS OF TECHNOLOGICAL DESIGN

The designing of technological processes (TP) of machining begins with the study of service purpose of the part, its technical requirements, and norms of accuracy and program of release, analysis of an opportunity of the enterprise on processing the given part.

The designing of TP represents a multi alternative task, the correct solution of which requires the realization of a number of calculations. Before beginning the designing of kinds of processing of blank surfaces and methods of achievement of their accuracy appropriate to the requirements of the drawing, the type of manufacturing equipment existing at the shop must be defined or established.

For low accuracy initial blanks, TP begins with rough processing of surfaces having greatest stocks. Stocks are removed in first turn from those surfaces on which the defects are possible. This is done for the purpose of the prompt elimination of spoilage.

The step is further designed with a principle of processing at first rough, and then more exact (accurate) surfaces. The most exact surfaces are processed in last turn.

At the end of the step, the minor operations (drilling of small holes, threading and tapping, removal (manufacturing) of chamfers, burring etc.) are also carried out. The easily damaged surfaces are processed at the final stage of TP.

At the requirement of the part quenching all minor surfaces are necessarily processed finally before the quenching, exact surfaces - previously, but they are not rougher than ninth grade of tolerance, saving stocks for final processing. The final processing of surfaces with the exact sizes is made after thermal operations.

For the considered part ("shaft") during the first operation, the surface of the shaft Ø40t7 should be processed, because it will be the base surface for the subsequent operation. Since it is required to supply accuracy of mutual arrangement to surfaces Ø30g6 and conical surface C=1:10, during the second operation it is necessary to use a self-centering chuck with center of a right side.

For increase of accuracy of the positioning of preliminary drilling of blank in the first operation at first it is required to process an end face of blank and to drill a center hole.

For drawing up of a TP route it is required previously to define the processing quantity of each surface. For this purpose, it is better to take the surface with the most exact size and to make a sequence of processing. Thus stocks are consecutive "covered" on the final (design) size, which allows us to receive the intermediate technological sizes. In our task the most exact external size is Ø30h7. It should be processed with 7th grade of tolerance, before - with 9th grade of tolerance, and earlier - with 11th grade of tolerance. We begin to write down the technological sizes from the end (design size is written first) and we go from the right hand to the left, for example: 34.78h12 → 32.68h9 → 31.08h7 → 30g6.

If it is necessary to carry out heat treatment (quenching, tempering and so on) we shall write the route of processing:

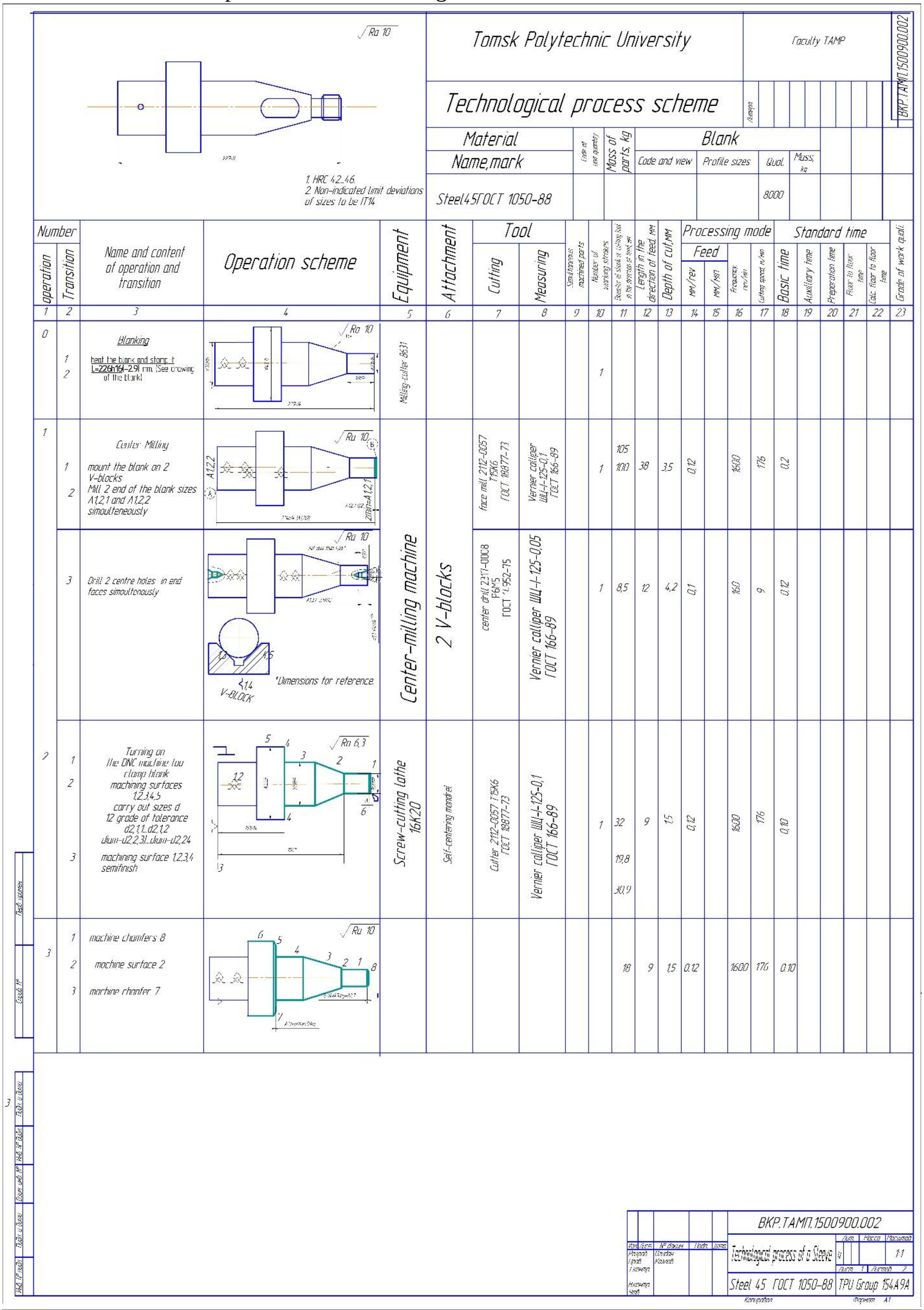
35h16 → 31.13h11 → 30.48h9 → Heat treatment → 30h7.

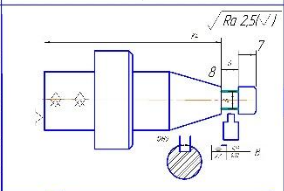
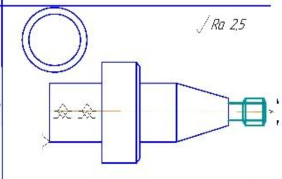
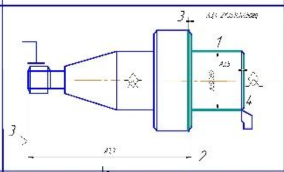
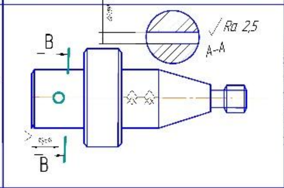
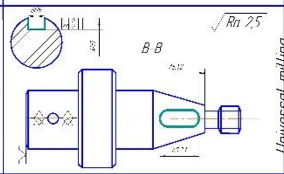
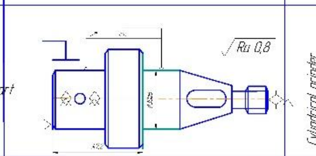
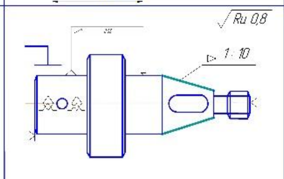
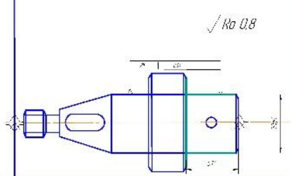
$2Z_{min} = 1.8$ *mm* $2Z_{min} = 0.4$ *mm* $2Z_{min} = 0.32$ *mm*

Such sequence allows avoiding one operation (before heat treatment with 9th grade of tolerance), however it can result in the increase of the possibility of the occurrence of a spoilage and hence, increase in the cost price of the part manufacturing.

In tab. 3.1 at first we write down a sequence of processing and operational sketches, but we shall calculate values of the intermediate technological sizes later, after the calculation of minimal stocks of processing (tab. 4.1). In operational sketches we shall write intermediate technological sizes approximately at first. Then we shall write a new table of the technological route where we shall write only definitive technological sizes.

Table 3.1. Route of the part "shafts" machining



| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4<br>5<br><br>6<br>7 | Turn surface to create a ridge between shaft and the thread head with a diameter of h16,14...d(-0,5 ...1)mm and round the edges<br>turn surface of chamfer 7 A2,6=2js14x45deg<br>turn surface of chamfer 8 | <br> | Thread-cutting(die) lathe 16K20 | Self-centering mandrel | Cutter 2102-0055 T15K6 ГОСТ 18877-73 | Micrometre MK50-1 ГОСТ 6507-90.<br>Templet for chamfer 45°. | | 1<br>1 | 30,5<br>19,5 | 51<br>2,7 | 0,331<br>2,7 | 0,32<br>0,5 | | 1600<br>1600 | 176<br>176 | 0,11<br>0,09 | | | | |
| | 4<br>1<br>6 | Threading<br>Mount and take off part<br>make a thread with a die tool a M20-8g thread 1, | <br> | | | Cutter 2102-0055 T15K6 ГОСТ 18877-73 | Micrometre MK50-1 ГОСТ6507-90.<br>Templet for chamfer 45°. | | 1 | 5,0 | 6,0 | 2,5 | 0,15 | | 1800 | 28,3 | 0,04 | | | | |
| 3 | 1<br>2<br><br>3<br>4 | turning operation<br>clamp blank<br>Turn surface the other way around to machine d 31,7h12<br>turn surface 1 and 2<br>turn chamfer 3<br>turn chamfer 5 | <br> | Universal milling machine ФУ251 | Special V Block | Two flute End mill | Turn surface the other way around in the secondpass(rough) | | 1 | 31,1 | 51 | 1,95 | 0,5 | | 1500 | 176 | 0,068 | | | | |
| 4 | <br>1<br>2 | Drilling<br>Mount and take off the part<br>drill key-slot maintaining other sizes | <br> | Vertical drilling machine 2H125 | Drill jig conductor | Drill Ф5 P6M5 ГОСТ 10903-77 | Vernier calliper ШЦ I-125-0,1 ГОСТ 166-89 | | 1 | 8,0 | 15,0 | 8,0 | $S_{vert}$ -0,007 mm/rev<br>$S_{lx}$ -0,022 mm/rev | | 1000 | 25,12 | 0,375 | | | | |
| 4 | <br>1<br>2 | milling<br>Mount and take off the part<br>Mill key-slot maintaining other sizes | <br> | Universal milling machine ФУ251 | Special V Block | Two flute End mill | Vernier calliper ШЦ I-125-0,1 ГОСТ 166-89 | | 1 | 8,0 | 15,0 | 8,0 | $S_{vert}$ -0,007 mm/rev<br>$S_{lx}$ -0,022 mm/rev | | 1000 | 25,12 | 0,375 | | | | |
| 5 | <br>1<br>2 | Heat treatment<br>Quenching<br>Annealing the part to HRC 42...46 | | | | | | | | | | | | | | | | | | | |
| 6 | <br>1<br>2 | Cylindrical grinding<br>Mount and remove the part<br>Grind surface 1 | <br> | Cylindrical grinder 3M150B | Self centering mandrel | ПП 200x10x32 22A 40 CM2 K5 6 ГОСТ 2424-83 | Micrometre MK50-1 ГОСТ 6507-90. | | 11 | 30 | 50,5 | 0,331 | $S_{1x}$ -5 mm/rev | | 2350 | 1683(28м/с) | 0,225 | | | | |
| 7 | <br>A<br>1 | cylindrical grinding<br>Mount part<br>Grind surface 1 | <br> | Surface grinding lathe 3E710A | Electromagnetic table | ПП 200x32x76 22A 40 CM2 K5 6 ГОСТ 2424-83 | Vernier calliper ШЦ-I-125-0,05 ГОСТ 166-89 | | 13 | Ф200 | 30,5 | 0,5 | $S_{1x}$ -5 mm/rev | | 1670 | 104,8 (17,5м/с) | 0,832 | | | | |
| 8 | B<br>2 | Mount and remove part<br>Grind surface 2 | <br> | | | | Micrometre MK50-1 ГОСТ 6507-90. | | 11 | Ф200 | 30,5 | 0,436 | $S_{1x}$ -5 mm/rev | | 1670 | 104,8 (17,5м/с) | 0,704 | | | | |
| 9 | | metal working<br>Control<br>Control the size and the surface roughness according to the requirements of the drawing | | | | | | | | | | | | | | | | | | | |

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## 4. CALCULATION of ALLOWANCES

**Stock** (allowance) is a layer of a material, removed in machining. Its minimal thickness $Z_{min}$ depends on many factors, but the major ones are:

1. Roughness of the surface received from previous machining (index i-1) - Rz $i\text{-}_1$;
2. Thickness of defective layer of the surface received from previous machining - Tdef $i\text{-}_1$;
3. Curvature (warp) of the surface received from previous machining - ρ $i\text{-}_1$;
4. Error of basing and fastening received at considered machining (index i) - εi.

If stock is less minimal, the traces from the previous machining will stay, which is not allowable. Stock is removed per one or several cuts, if the thickness is too large.

Minimal stock for considered machining (operation) is defined from the tables or calculated by the formulas, where we can calculate minimal stock taking into account the seldom probability of occurrence in the same direction of warp of a surface received from previous machining ($\rho_{i-1}$) and error of basing and fastening received at considered machining ($\varepsilon_i$) for rotation surfaces:

$$2z_{\min.i} = 2\cdot\left(R_{z.i-1} + T_{\partial.i-1} + \sqrt{(\rho_{i-1}^2 + \varepsilon_i^2)}\right), \qquad (4.1)$$

Where $2z_{min\ i}$ is a minimal stock of rotation surfaces for considered machining.

It is better to calculate minimal stock taking into account the probability of occurrence in the same direction of warp of a surface received at the previous manufacturing ($\rho_{i-1}$) and error of basing and fastening received at considered manufacturing ($\varepsilon_i$) for rotation surfaces:

$$2z_{\min.i} = 2\cdot\left(R_{z.i-1} + T_{\partial.i-1} + \rho_{i-1} + \varepsilon_i\right), \qquad (4.2)$$

For flat surfaces (non-rotating surfaces) minimal stock is calculated by the formula:

$$z_{min\ i} = Rz_{i-1} + T_{def\ i-1} + \rho_{i-1} + \varepsilon_i. \qquad (4.3)$$

### 4.1. Stock calculation for the surface processing Ø40t7

We make stock calculations of the surface processing Ø40t7 by drawing up of tab. 4.1, in which the technological route of the surface processing and all values of stock elements are written consistently.

Total value Rz and Tdef, describing quality of a surface of blank from cold rolling process, is determined from tab. 27 [4, page 66]. For each subsequent technological transition these values are determined from tab. 29 [4, page 67].

We determine total deviation of a warp error $\rho_{warp}$ and displacement $\rho_{dis}$ by the formula:

$$\rho = \sqrt{(\rho_{dis}^2 + \rho_{warp}^2)}\,, \qquad (4.3)$$

Where: $\rho_{dis}$ - error of blank on displacement concerning an axis in a radial direction; $\rho_{warp}$ - error of blank on warp.

We find size of a residual spatial deviation of a blank for a surface processing Ø30h7.
The error of blank on displacement is defined from tab. 32 [4, page 72]:
$\rho_{dis}$= 0.360 mm = 360 μm.
The blank error of a warp is defined by product of length of blank $\ell$ on specific warp $\Delta_w$, which depends on the method of blank manufacturing on the previous operation:

$$\rho_{warp} = \Delta_w \times \ell = 0.12 \times 60 = 7.2 \ \mu m,$$

Where specific warp $\Delta_w$ is defined from tab. 32 [4, page 72].

Total deviation of an error on warp and displacement:

$$\rho_0 = \sqrt{(360^2 + 7.2^2)} = 360.4 \mu m \approx 360 \ \mu m.$$

Residual spatial deviation of the blank $\rho_0$ =360 microns.

After that we find value of a residual spatial deviation after preliminary turning (rough turning) using the factor of residual warp $k_{warp}$ and warp of blank $\rho_{blank}$: $\rho_1 = k_{warp} \times \rho_{blank} = 0.08 \cdot 360 = 30 \mu m.$

Residual spatial deviation after semi-finish (fair) turning:

$$\rho_2 = k_{warp} \times \rho_{blank} = 0.02 \cdot 360 = 7{,}2 \approx 10 \ \mu m.$$

Residual spatial deviation after grinding: $\rho_3 = k_{warp} \times \rho_{blank} = 0.1 \cdot 50 = 5 \ \mu m.$

Table 4.1. Calculation of stocks and limit technological sizes for technological transitions for surfaces manufacturing

| Technological transitions | Elements of stock, μm | | | | Calculated stock, $2z_{min}$ ,μm | Calculated size $d_c$, mm | Tole-rance T, μm | Limit sizes, mm | |
|---|---|---|---|---|---|---|---|---|---|
| | $R_Z$ | $T$ | $\rho$ | $\varepsilon$ | | | | $d_{min}$ | $d_{max}$ |
| External surface ($Ø\mathbf{40}t7\binom{+0{,}073}{+0{,}048}$) | | | | | | | | | |
| Hot stamped (h16) | *160* | *150* | *360* | --- | | *44h16* | 1600 | 42.34 | 43.94 |
| Turning: | | | | | | | | | |
| *rough* (h11) | *40* | *40* | *30* | *100* | 2*770 | 40.8h11 | 160 | 40.64 | 40.8 |
| *semifinish* (h9) | *10* | *10* | *10* | *10* | 2*120 | 40.4h9 | 62 | 40.333 | 40.395 |
| Heat Treatment HRC 42…46 | *20* | *50* | *50* | --- | – | | | | |
| grinding (t7) | *6* | *6* | *5* | *10* | 2*130 | 40t7 | **25** | 40.048 | 40.073 |
| Eternal surface (shaft) $\boldsymbol{Ø30g6}\binom{-0.007}{-0.02}$ | | | | | | | | | |
| Hot stamped (h16) | *160* | *150* | *360* | --- | | 34h16 | *1600* | 32.44 | 34.04 |
| Rough turning (h11) | *40* | *40* | 30 | *100* | 2*770 | 30.9h11 | 160 | 30.74 | 30.9 |
| Semi-finish(h9) | *10* | *10* | *10* | *10* | 2*120 | 30.5h9 | 62 | 30.36 | 30.422 |
| Heat Treatment HRC 42…46 | *20* | *50* | *50* | --- | – | | | | |
| Rough round grinding (h7) | *6* | *6* | *5* | *10* | 2*130 | 30.1h7 | 25 | 30.037 | 30.062 |
| Finish round grinding (g6) | *3.2* | *4* | *3* | *5* | 2*22 | 30g6 | 13 | 29.98 | 29.993 |

| External surface (length of shaft) **220h14**($_{-1.15}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Stamped blank (side B) (h16) | *160* | *250* | *350* | --- | – | 225.8h16 (from unprocessed surface B to unprocessed surface A) | 2.9 | 222.88 | 225.78 |
| Mill side B (h14) | *40* | *40* | *21* | 120 | 880 | **222.0 h14** (from unprocessed surface B to processed surface A) (already calculated) | ~~1.150~~ | ~~220.88~~ (already calculated) | ~~222.03~~ (already calculated) |
| Stamped blank (side A) (h14) | *160* | *250* | *350* | - | – | 222.0 h14 (from unprocessed surface B to processed surface A) | 1.150 | 220.88 | 222.03 |
| Mill side A (h14) | *40* | *40* | *21* | 120 | 880 | 220h14 (between processed surfaces A & B) | 1.150 | 218.85 | 220.0 |

As the blank is maintained on a self-centering mandrel, we shall define an error of installation by the formula:

$$\varepsilon_i = \sqrt{(\varepsilon_b^2 + \varepsilon_f^2)} = \varepsilon_f = 100 \mu m,$$

Where an error of basing $\varepsilon_b \to 0$ (since at installation of the blank in the attachment the technological base coincides with design base); $\varepsilon_f$ *is* an error of fastening (clamping).

For the part "shaft" minimal stocks are determined by the equation (4.1) for processing a surface Ø**40**t7$\left(^{+0,073}_{+0,048}\right)$:

- for the preliminary turning (with 11th grade of tolerance):

$$2z_{\min.i} = 2 \cdot \left( R_{z.i-1} + T_{\partial.i-1} + \sqrt{(\rho_{i-1}^2 + \varepsilon_i^2)} \right) = 2 \cdot \left( 160 + 150 + \sqrt{(360^2 + 100^2)} \right) = 1840 \mu m$$

- for the semi-finish (fair) turning (with 9th grade of tolerance):

$$2z_{\min.i} = 2 \cdot \left( 40 + 40 + \sqrt{(30^2 + 10^2)} \right) = 369 \ \mu m;$$

- for the grinding (with 7th grade of tolerance):

$$2z_{\min.i} = 2 \cdot \left( 20 + 50 + \sqrt{(50^2 + 10^2)} \right) = 68.3 \ \mu m.$$

It is better for us to take into account the small scale manufacturing of the part and for increasing of manufacturing reliability we shall calculate minimal stock (allowance) of surface Ø40t7 by the formula (4.2) taking into account the probability of occurrence in the same direction of warp ($\rho_{i-1}$) and error of basing and fastening ($\varepsilon_i$) for rotation surfaces:

- for the preliminary turning (with 11 grade of tolerance):

$$2z_{\min.i} = 2 \cdot \left( R_{z.i-1} + T_{\partial.i-1} + \rho_{i-1} + \varepsilon_i \right) = 2 \cdot (160+150+360+100) = 2 \times 770 = 1540 \ \mu m;$$

- for the semi-finish (fair) turning (with 9 grade of tolerance):

$$2z_{\min\ i} = 2 \cdot (40 + 40 + 30 + 10) = 2 \times 120 = 240 \ \mu m;$$

- for the grinding (with 7 grade of tolerance):

$2z_{min\ i}$ = 2(20 + 50 + 50 + 10) = *2×130 = 260* µm.

Results of calculations by the formula (4.2) are written in tab. 4.1.

### 4.2. Stock calculations for a surface $Ø30g6(^{-0.007}_{-0.02})$

We do calculations of processing stocks for a surface $Ø30g6(^{-0.007}_{-0.02})$by drawing up of tab. 4.1, in which the technological route of a surface processing and all values of stock elements are written consistently. Total values Rz and $T_{def}$, describing quality of a cold rolling blank surface are determined with the help of tab. 27 [4, page 66]. For each subsequent technological transition these values are determined using tab. 29 [4, page 67].

We determine total deviation of a warp error $\rho_{warp}$ and displacement $\rho_{dis}$ by the formula (4.3):

$$\rho = \sqrt{(\rho_{dis}^2 + \rho_{warp}^2)}\ ,$$

Where: $\rho_{dis}$ - error of blank on displacement concerning an axis in a radial direction; $\rho_{warp}$ - error of blank on warp.

The error of blank on displacement is defined from tab. 32 [4, page 72]:

$\rho_{dis}$= 0.5 mm = 500 µm.

The blank error of a warp is defined by product of length of blank $\ell$ on specific warp $\Delta_w$, which is dependent on the method of blank manufacturing in the previous operation:

$$\rho_{warp} = \Delta_w \times \ell = 0.12 \times 52 = 6.24\ \mu m,$$

Where specific warp $\Delta_w$ is defined from tab. 32 [4, page 72].

Total deviation of an error on warp and displacement:

$$\rho_0 = \sqrt{(350^2 + 6.24^2)} \approx 360 \mu m$$

Residual spatial deviation of blank $\rho_0$ =360 µm.

We find size of a residual spatial deviation for a have processed surface with 11 grade of tolerance

$$\rho_1 = \sqrt{C_0^2 + (\Delta_b \cdot L)^2} = \sqrt{2.5^2 + (0.6 \cdot 50)^2} \approx 30\ \mu m.$$

As the blank is maintained between centers, we shall define the error of installation by the formula:

$$\varepsilon_i = \sqrt{(\varepsilon_b^2 + \varepsilon_f^2)} = \varepsilon_f = 100 \mu m\ ,$$

Where an error of basing $\varepsilon_b \rightarrow 0$ *(*since at installation of blank in the attachment the technological base coincides with design base); $\varepsilon_f$ *is* an error of fastening (clamping).

Minimal stocks for processing the surface $Ø30g6(^{-0.007}_{-0.02})$ are calculated by the equation (4.2) for increasing of manufacturing reliability:

### 4.3. Stock calculations for a surface 220h14

We make calculations of processing stocks by the formula (4.3) for a surface 220h14 ($_{-1.15}$) by drawing up of tab. 4.1, in which the technological route of the surface processing and all values of stock elements are written consistently.

It is better to define warp of a surface received at the previous manufacturing ($\rho_{i-1}$) and error of basing and fastening received at considered manufacturing ($\varepsilon_i$) from machinist handbook. We shall write these values in formula (4.3):

- for the preliminary turning of right face end of the blank (with 14 grade of tolerance):

$$z_{min\ i} = Rz_{i-1} + T_{def\ i-1} + \rho_{i-1} + \varepsilon_{i.} = 160 + 250 + 350 + 120 = 880\ \mu m;$$

Results of accounts by the formula (4.3) are written in tab. 4.1.

**4.4. Calculation of technological sizes**

**4.4.1. Calculation of technological sizes for machining Ø40h14**

We make calculations of technological sizes with the help of size circuit analyses. We draw sizes circuits for the Ø30h7 ($_{-0.021}$) (Fig. 4.1). Technological size $A_3$ has to be equal (by rough calculation) to design size K. Sometimes technological size coinciding with design_size has to be more accurate (with less grade of tolerance but with the same fundamental deviation) if it is necessary to solve size circuit. This size $A_3$ is processed in second technological transition of sixth operation, and that is why we can mark it by symbol $A_{6.2.}$ We can write: $A_3$ = K = $A_{6.2}$ = Ø30h7 ($_{-0.021}$).

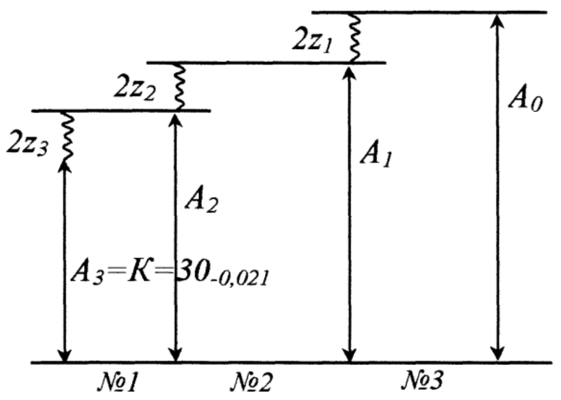



***Fig. 4.1***. Sizes circuits for calculations of technological sizes for processing external surface **Ø30h7**

Here and further we shall write technological size with index, which shows number of technological operation (first figure) and number of technological transition (second figure) were this technological size is processed. For example, technological size $A_{6.2}$ is processed in sixth operation and in second technological transition (in second technological transition of sixth operation).

Stock $2z_3$ in size circuit №1 is equal to $2z_{6.2:}$ $2z_3 = 2z_{6.2}$.

Here and further we shall write stock of technological size with index, which shows number of technological operation (first figure) and number of technological transition (second figure) where this stock is removed (where the technological size with the same index is processed). For example, stock $2z_{6.2}$ is removed in sixth operation and in second technological transition (in second technological transition of sixth operation), were technological size $A_{6.2}$ is processed.

1. We shall find technological size $A_2$ using size circuit №1:

$2z_{3min} = A_{2min} - A_{3max}$;

From which we shall calculate minimal technological size $A_{2min}$:

$A_{2min} = A_{3max} + 2z_{3min} = A_{5.2max} + 2z_{5.2min} = = 30 + 0.08 = 30.08$ mm;

$A_{2max} = A_{2min} + TA_2 = 30.08 + 0.062 = =30.142$ mm,

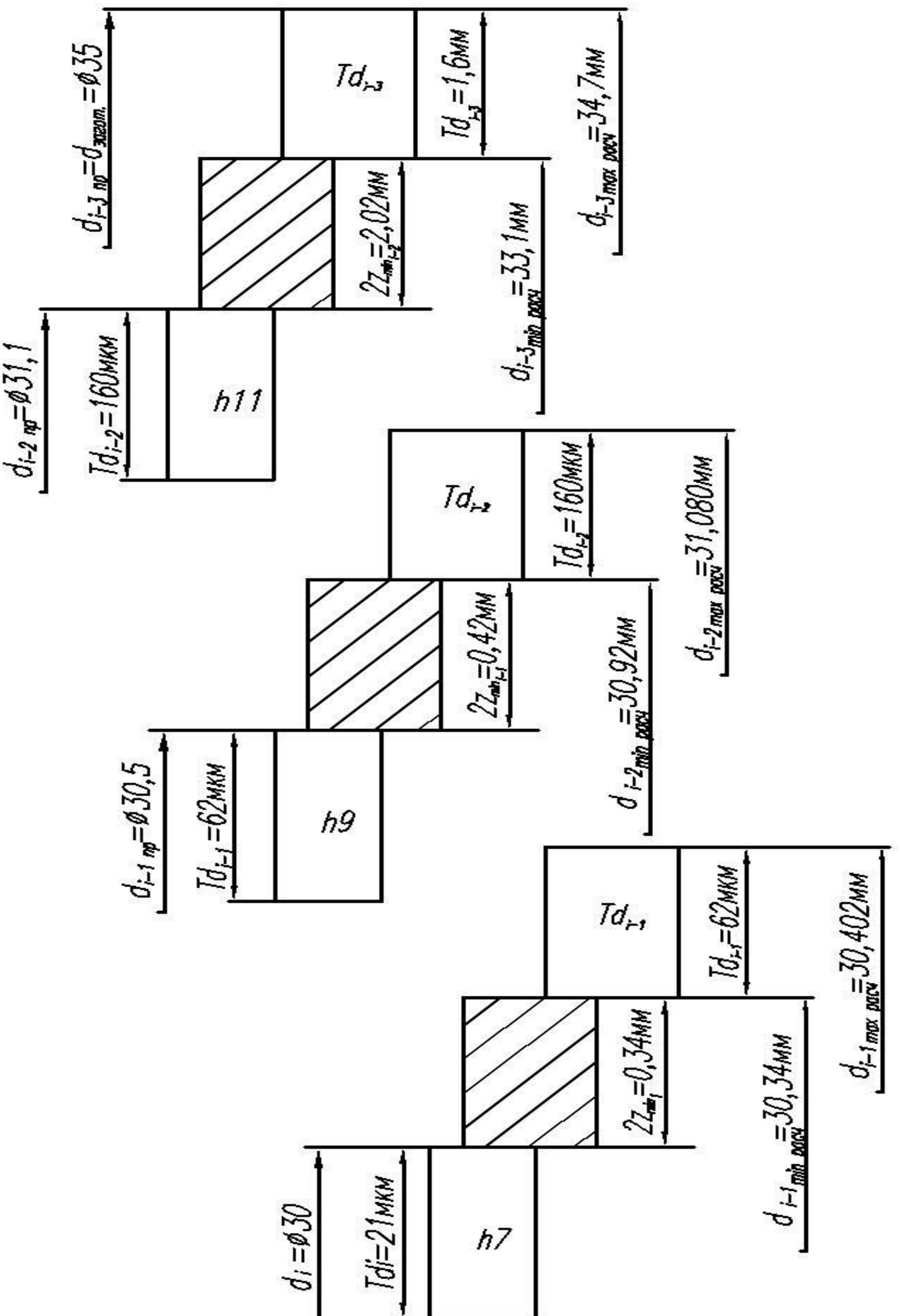



Рис. 4.2. Поле припусков и допусков технологических размеров при обработке ***наружной*** поверхности **Ø30h7**

Where $TA_2$ = IT9 = 62 µm = 0.062 mm – in accordance with technological route of size Ø30h7 processing (see tab. 3.1 and tab. 4.1). We find minimal stock ($2z_3$ = $2z_{6.2}$) in tab. 4.1.
Calculated (previous determined) technological size $A_2$ is:
$A_{2cal} = 30.142_{-0.062}$ mm – after finish turning.

We round the base (nominal) size in greater value (as a "shaft") with tenth of millimeter accuracy:
$A_{2acc} = A_{2.4} = Ø30.2h9(_{-0.062})$ mm – is preliminarily (by rough calculation) accepted technological size $A_2$ which is obtained after finish turning (with 9 grade of tolerance) in fourth technological transition of second operation.
$A_{3acc} = K = A_{6.2} = Ø30h7\ (_{-0.021})$ mm – is preliminarily (by rough calculation) accepted technological size $A_3$ which is obtained after round grinding (with 7th grade of tolerance) in second technological transition of sixth operation.
2. We shall find technological size $A_1$ using size circuit №2:
$2z_{2min} = A_{1min} – A_{2max}$;
$A_{1min} = A_{2max} + 2z_{2min} = 30.2 + 0.42 = 30.62$ мм;
$A_{1max} = A_{1min} + TA_1 = 30.62 + 0.16 = 30.78$ мм;
$A_{1cal} = 30.78_{-0.16}$ mm – after rough turning.
We round the base size in greater value (as a "shaft") with tenth of millimeter accuracy:
$A_{1acc} = A_{2.3} = Ø30.8h11(_{-0.16})$ mm – is preliminarily (by rough calculation) accepted technological size $A_1$ which is obtained after rough turning (with 11th grade of tolerance) in third technological transition of second operation.
3. We shall find technological size $A_0$ (diameter of a blank) using size circuit №3:
$2z_{1min} = A_{0min} – A_{1max}$;
$A_{0min} = A_{1max} + 2z_{1min} = 30.8 + 2.02 = 32.82$ mm;
$A_{0max} = A_{0min} + TA_0 = 32.82 + 1.600 = 34.42$ mm;
$A_{0cal} = 34.42\ _{-1.6}$ mm.
We accept $A_0 = A_{02} = Ø35h16(_{-1.6})$ mm – is preliminarily (by rough calculation) accepted diameter of the blank in accordance with standard for diameter of cold rolling production.
We recalculate stock:
$2z_{1min} = A_{0min} – A_{1max} = 33.4 – 30.8 = 2.6$ mm;
$2z_{1max} = A_{0max} – A_{1min} = 35 – 30.64 = 4.36$ mm.
Depth of cut for calculation of cutting speed is calculated by the formula: $t = 2z/2$.
That maximal depth of cut (it is necessary to calculate maximal cutting force for calculation of clamping force of attachment) $t_{max} = 2z_{max}/2 = 4.36 / 2 = 2.18$ mm.
Minimal depth of cut: $t_{min} = 2z_{min}/2 = 2.6 / 2 = 1.3$ mm;
Average depth of cut (it is necessary to calculate cutting speed):
$t_{av} = (t_{max} + t_{min})/2 = (2.18 + 1.3) / 2 = 1.741$ mm.

Further we shall not recalculate stock and depth of cut because we shall define more precisely technological sizes (after size analysis of technological process).

### 4.4.2. Calculation of technological sizes in machining hole Ø20H7

We draw sizes circuits for the hole Ø20H7 ($^{+0.021}$) processing (fig. 4.2).

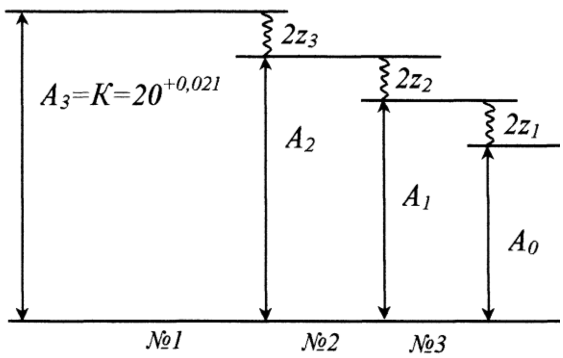



***Fig. 4.2***. Sizes circuits for calculations of technological sizes for processing internal surface **Ø20H7**

Technological size $A_3$ has to be equal (*by rough calculation*) to design size $K$. We can write: $A_3 = K = A_{8.2} =$ $= 20H7\ (^{+0.021})$.

1. We shall find technological size $A_2$ using size circuit № 1:

$2z_{3min} = A_{3min} – A_{2max}$;

$A_{2max} = A_{3min} - 2z_{3min} = 20 - 0.302 =$ $=19.698$ мм;

$A_{2min} = A_{2max} - TA_2 = 19.698 - 0.13 =$ $=19.568$ мм;

$A_{2cal} = 19.568^{+0.13}$ mm – after boring.

We round the base size in smaller *(*lesser*)* value (as a "hole") with tenth of millimeter accuracy:

$A_{2acc} = A_{1.5} = Ø19.5H11\ (^{+0.13})$ mm – is preliminarily (by rough calculation) accepted technological size $A_{1.5}$ which is obtained after boring (with 11 grade of tolerance) in fifth technological transition of first operation.

$A_{3acc} = K = A_{8.2} = Ø20H7(^{+0.021})$ mm - is preliminarily (by rough calculation) accepted technological size $A_3$ (final) which is obtained after internal grinding (with 7 grade of tolerance) in second technological transition of eighth operation.

2. We will find technological size $A_1$ using size circuit № 2:

$2z_{2min} = A_{2min} – A_{1max}$;

$A_{1max} = A_{2min} - 2z_{2min} = 19.5 - 2.572 = 17.928$ mm;

$A_{1min} = A_{1max} - TA_1 = 17.928 - 0.43 = 17.498$ mm;

$A_{1cal} = 17.498\ ^{+0.43}$ mm – after drilling of hole.

We round the base size in slightly greater value (as the decreasing of minimal stock on 0.002 mm is not sufficient for rough drilling) with tenth of millimeter accuracy:

$A_{1acc} = A_{1.4} = 17.5H14(^{+0.43})$ mm – is preliminarily (by rough calculation) accepted technological size $A_1$ which is obtained after drilling of hole (with 14 grade of tolerance) in fourth technological transition of first operation.

3. We can find technological size $A_0$ (diameter of a blank hole) using size circuit №2 (but it is not need, because we drill a hole in blank without piercing hole):

$2z_{1min} = A_{1min} – A_{0max}$;

$A_{0max} = A_{1min} - 2z_{1min} = 17.5 – 2.02 = 15.48$ mm;

$A_{0min} = A_{0max} - TA_0 = 15.48 - 1.1 = 14.38$ mm,
Where $TA_0$ = IT16 = 1100 μm = 1.1 mm – tolerance of pierced hole (with 16th grade of tolerance.)
$A_{0cal} = 14.38^{+1.1}$ mm (if the blank has a hole, for example, by piercing in forging process.)
We accept the hole diameter in the blank $A_{0acc} = A_0$ = Ø14.3H16 ($^{+1.1}$) mm (only in case if the blank enter into production with previously pierced hole.)

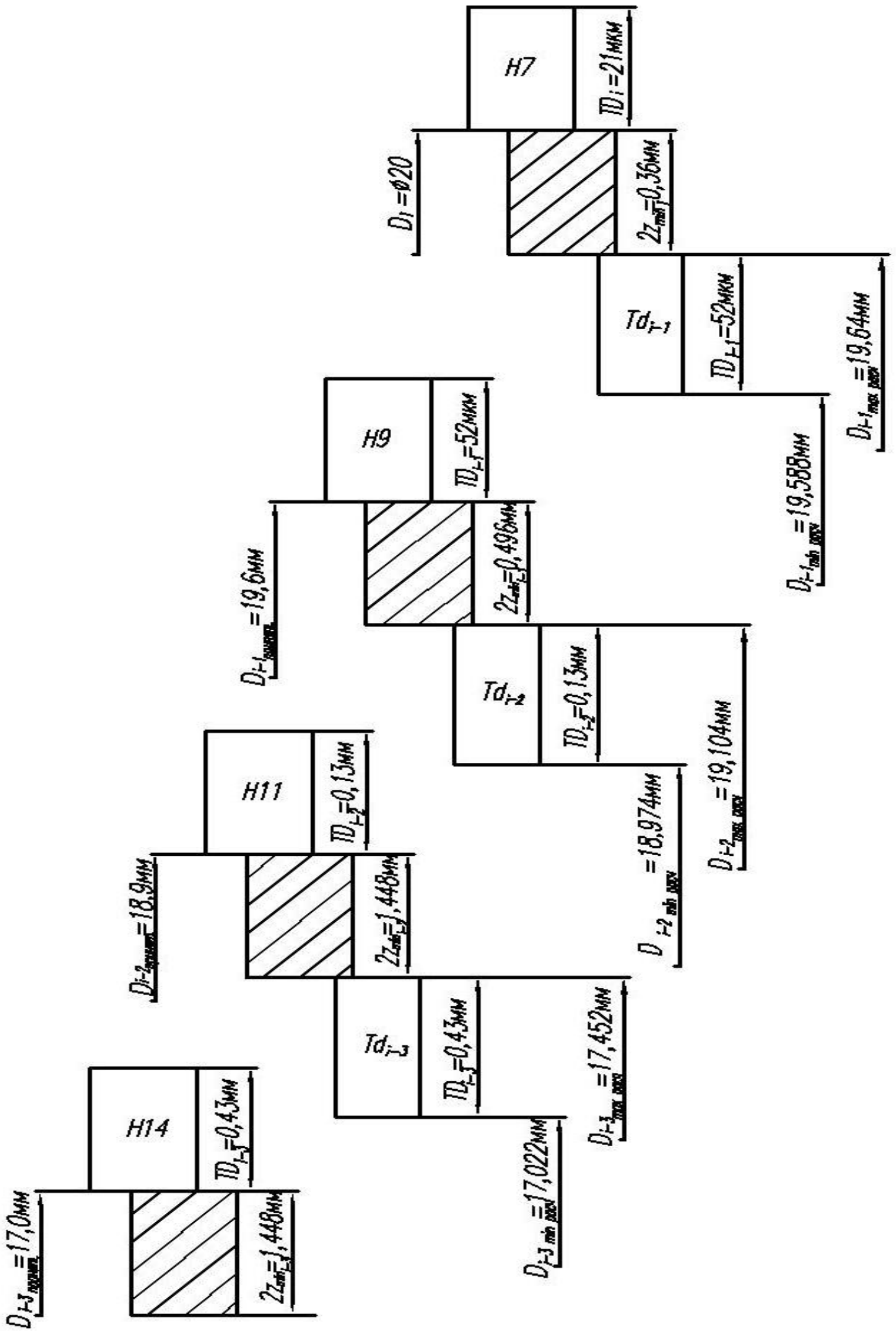



Рис. 4.4. Поле припусков и допусков технологических размеров при обработке ***внутренней*** поверхности **Ø20H7**

### 4.4.3. Calculation of technological sizes for processing 50h9

We draw sizes circuits for processing of detail on length with size 50h9 ($_{-0.062}$) (fig. 4.3). Technological size $A_4$ has to be equal (*by rough calculation*) to design size $K_1$. We can write: $A_4 = K_1 = A_{7.2} = 50h9(_{-0.062})$ .

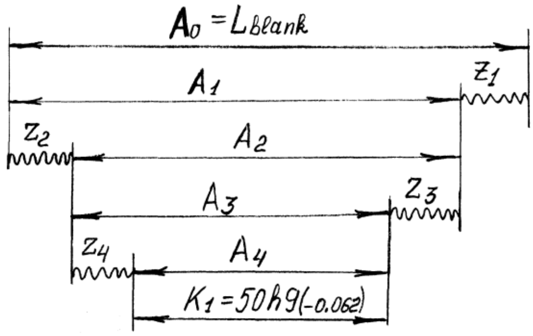



***Fig. 4.3***. Sizes circuits for calculations of technological sizes for processing of detail on length with size **50h9**

1. We will find technological size $A_3$ using size circuit №1:

$z_{4min} = A_{3min} – A_{4max}$;

or: $z_{4min} = A_{3min} – K_{1max}$;

$A_{3min} = K_{1max} + z_{4min}$=50+0.154=50.154 mm;

$A_{3max} = A_{3min} + TA_3 = 50.154 + 0.190 =$ =50.344 мм,

where $TA_3$ = 0.190 mm (tolerance of 9 grade of tolerance for the interval from 50 mm to 80 mm – for the size more than 50 mm in table of tolerances.)

$A_{3cal} = 50.344_{-0.19}$ mm – after grinding of right face side of sleeve.

We round the base size in greater value (as a “shaft”) with tenth of millimeter accuracy:

$A_{3acc} = A_{7.1} = 50.4h11(_{-0.19})$ mm – is preliminarily (by rough calculation) accepted technological size $A_3$ which is obtained after grinding of right face side of sleeve (with 11th grade of tolerance) on second technological transition of seventh operation.

2. We shall find technological size $A_2$ using size circuit №2:

$z_{3min} = A_{2min} – A_{3max}$;

$A_{2min} = A_{3max} + z_{3min} = 50.4 + 0.178 = 50.578$ mm

$A_{2max} = A_{2min} + TA_2 = 50.578 + 0.740 = 51.318$ mm

where $TA_2$ = 0.740 mm (tolerance of 14th grade of tolerance for the interval from 50 mm to 80 mm – for the size more than 50 mm in table of tolerances.)

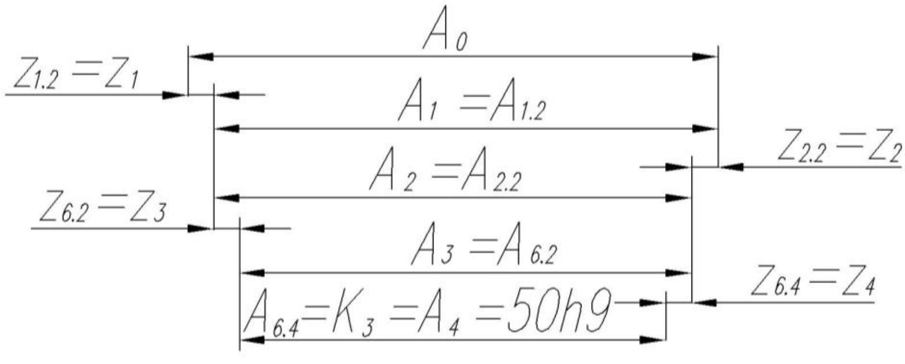



Рис. 4.5. Размерные цепи для расчета технологических размеров при обработке втулки по длине **50h9**

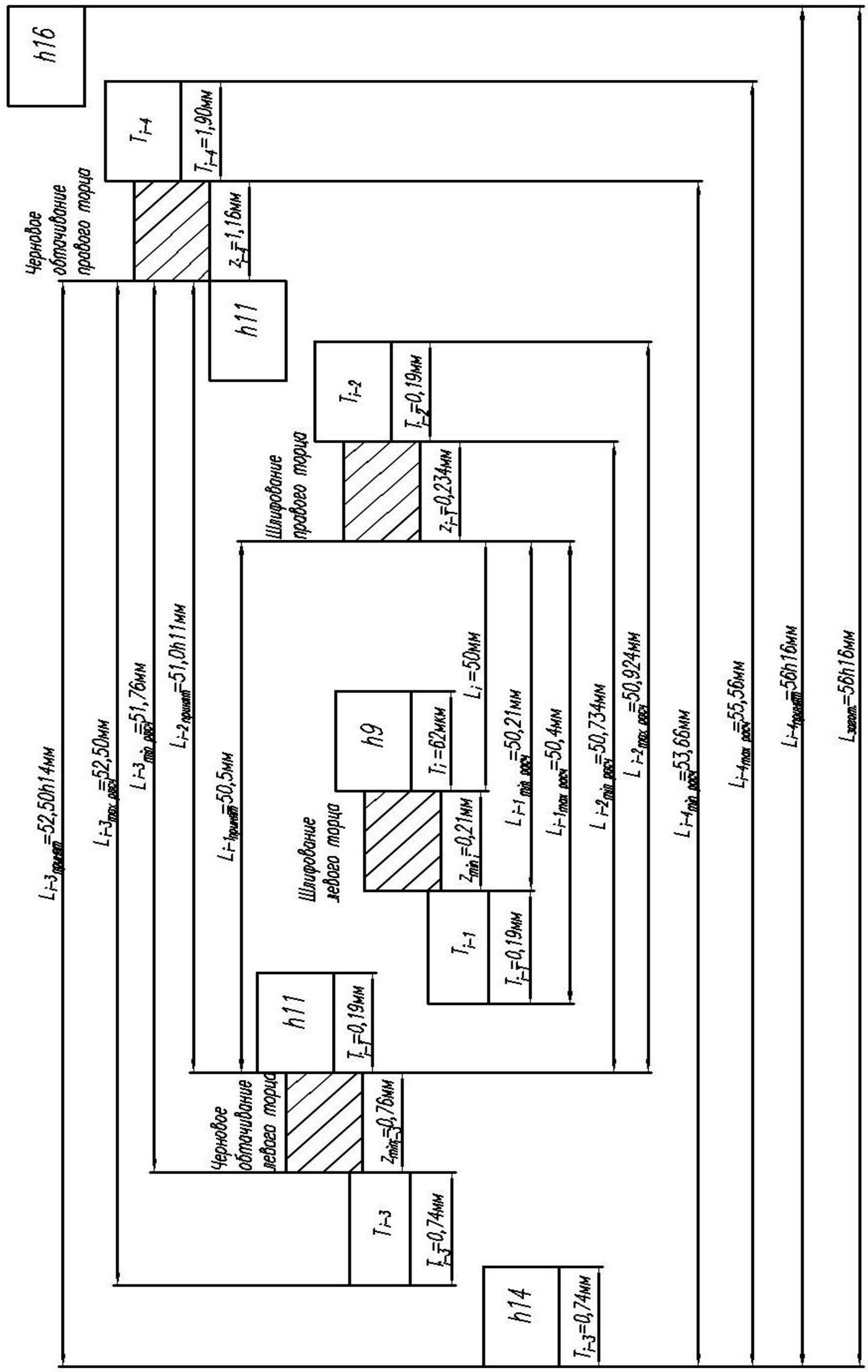



Рис. 4.6. Поле припусков и допусков технологических размеров при обработке ***наружной*** поверхности **50Н9**

$A_{2\,cal} = 51.318_{-0.74}$ mm.
We round the base size in greater value (as a "shaft") with tenth of millimeter accuracy:
$A_{2acc} = A_{2.2} = 51.4h14(_{-0.74})$ mm – is preliminarily (by rough calculation*)* accepted technological size $A_{2.2}$ which is obtained after rough turning of left face side of cartridge (with the 14th grade of tolerance) in second technological transition of second operation.
3. We shall find technological size $A_1$ using size circuit № 3:
$z_{2min} = A_{1min} – A_{2max}$;
$A_{1min} = A_{2max} + z_{2min} = 51.4 + 0.760 = 52.16$ mm;
$A_{1max} = A_{1min} + TA_1 = 52.16 + 0.740 = 52.90$ mm,
where $TA_1$= 0.740 mm (tolerance of 14th grade of tolerance for the interval from 50 mm to 80 mm – for the size more than 50 mm in table of tolerances.)
$A_{1\,cal} = 52.9_{-0.74}$ mm.
We accept: $A_{1acc} = A_{1.2} = 52.9h14(_{-0.74})$ mm – is preliminarily (by rough calculation) accepted technological size $A_{1.2}$ which is obtained after rough turning of right face side of cartridge (with 14 grade of tolerance) on second technological transition of first operation.
4. We shall find technological size $A_0$ using size circuit № 3:
$z_{1min} = A_{0min} – A_{1max}$;
$A_{0min} = A_{1max} + z_{1min} = 52.9 + 1.160 = 54.060$ mm;
$A_{0max} = A_{0min} + TA_0 = 54.060 + 1.900 = 55.960$ mm;
where $TA_0$= 1.9 mm (tolerance of 16th grade of tolerance for the interval from 50 mm to 80 mm – for the size more than 50 mm in table of tolerances.)
$A_{0\,cal} = 55.96_{-1.9}$ mm.
We accept: $A_{0acc} = A_0 = 56h16(_{-1.9})$ mm – is preliminarily (by rough calculation) accepted technological size $A_0$ (length of blank) which is obtained after cutting off with (by) slitting saw a rod (with 16th grade of tolerance) in zero (blanked) operation.

## 5. SIZE ANALYSIS of TECHNOLOGICAL PROCESS

The purpose of size analysis consists of the estimation of technological processes quality. We check and correct, if it is necessary, deviations of sizes comparing final technological sizes with design sizes given on the executive (work) drawing.
The initial data for the size analysis are:

1. Drawing of the part.
2. Drawing of initial blank.
3. Technological process of the part processing.

We draw general scheme of the part processing and select sizes circuits, into which design sizes are included. Component links (making parts) in technological size circuits are the technological sizes, which are specified in the technological documentation (sizes of initial blank and all sizes obtained at machining). The final technological sizes should coincide with the sizes specified on the drawing, i.e. with the design sizes. If such concurrence is not present, i.e. the technological size does not coincide with design size (design size is not maintained directly), it is necessary to reveal (to define) such size circuit, into which the considered design size and technological sizes are maintained for reception of the design size. Such design size is a closing link, and since it is required to execute it with given base (nominal) size and deviations, it is referred to as initial. Closing links in technological size circuits can be design and technological sizes, and also stocks for processing.
We consistently consider size circuits with one unknown technological size and we consider base value and deviations of this link. If there are several unknown technological sizes, we calculate the tolerances of the unknown sizes (usually by method of equal accuracy), and then we nominate values and deviations of all unknown technological sizes except for one, concerning which the decision will be made.
We draw general scheme of the part processing (fig. 5.1). Then we check the coincidence of final technological sizes with the sizes specified on the drawing.
1. $A_{7.2} = K_1 = 50h9(_{-0.062})$ i.e. design size $K_1$ is processed directly (enters) in the seventh operation and in the second technological transition by the technological size $A_{7.2}$;
2. $K_2$, $K_3$, $K_4$, $K_5$, $K_6$ are not processed directly, that is why it is necessary to reveal (to define) such size circuit, into which the considered design sizes ($K_2$, $K_3$, $K_4$, $K_5$ and $K_6$) and technological sizes are maintained for obtaining the design sizes. Those design sizes are closing links, and since it is required to execute them with the given base sizes and deviations, they are referred to as initials.

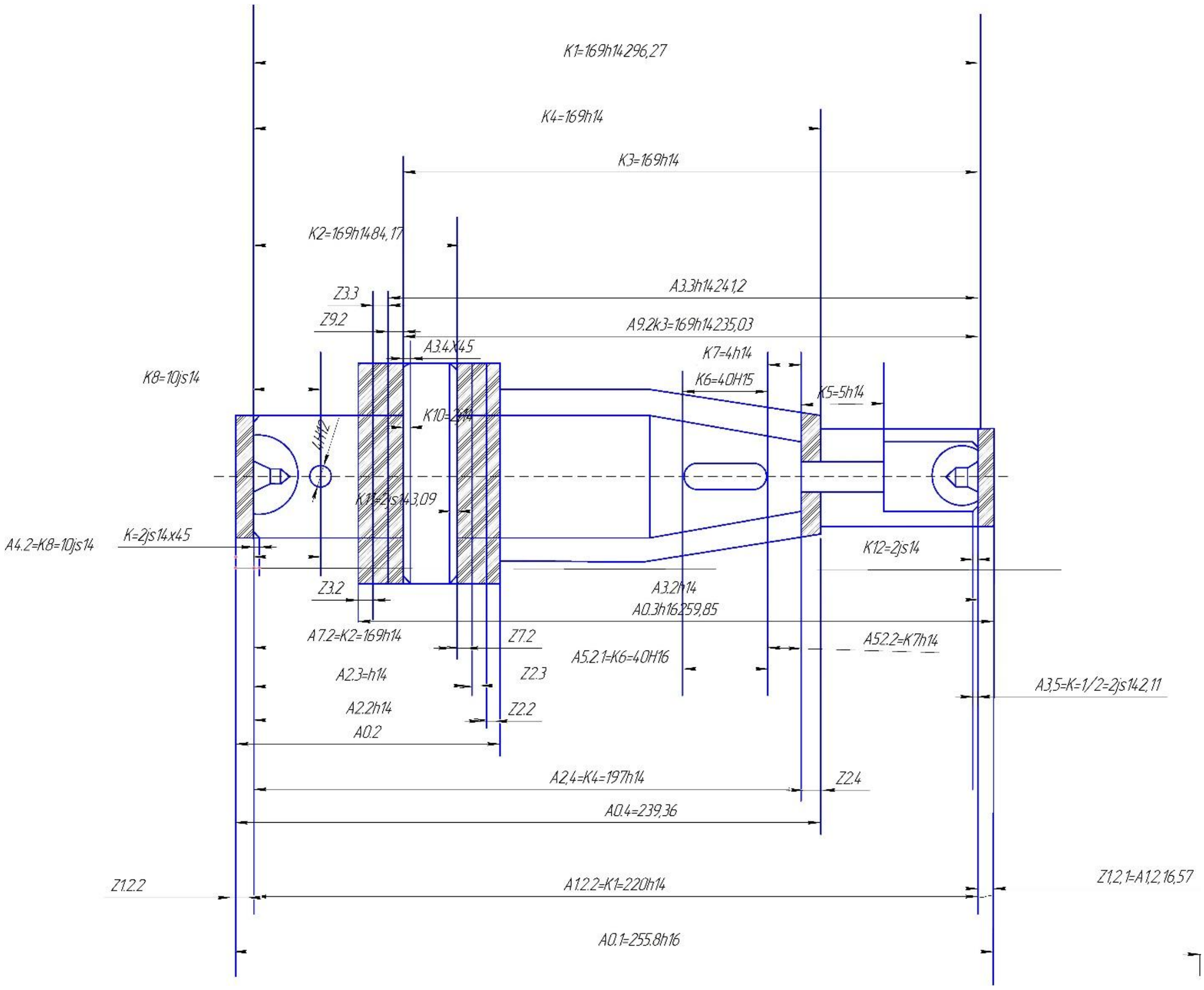


Fig. 5.1. Complex scheme of shaft machining in axial direction

We draw size circuits of a **desirable** design size machining (for example, fig. 5.2). Then we check the possibility of solving: it is necessary that

$$\sum TA_i \leq TA_\Delta. \quad (5.1)$$

If it is not there we need to reduce sizes tolerances (or tolerance of only one size) of components links. If our size circuit satisfies the equation (5.1), we may find technological sizes (base and deviations.)

### 5.1. Maintaining of chamfer size K$_3$ = 2j$_s$14 (±0.25) ×45º

For maintaining (obtaining at processing) size of left chamfer $K_3 = 2j_s14(\pm0.25)\times45^o$ in the general scheme (fig. 5.1) we select a size circuit (fig. 5.2), into which this design size $K_3$ enters, as it is not maintained directly.

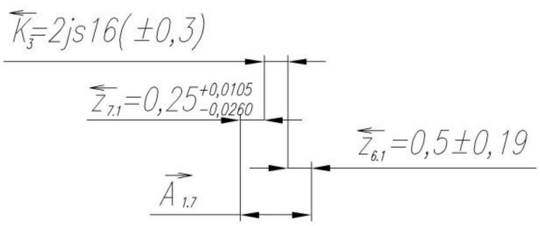



Рис. 5.2. Размерная цепь для расчета технологического размера $A_{1.7}$.

In the size circuit we select the size $X_3$ which is a part of chamfer, removed after grinding of the hole Ø20H7 (fig. 5.1). As the chamfer is bored under the angle 45º, its size in the axial direction will be equal to the size in radial direction. Changing of chamfer size in a radial direction is defined as a difference of half of diameters between final grinding hole with H7 (technological size $A_{8.2}/2$ = = Ø20H7 $(^{+0.021})/2$) and previous bored hole with H11 (technological size $A_{1.5}/2$= = *Ø19*.5H11 $(^{+0.13})/2$). The tolerances (deviations) thus also are divided half-and-half.

$$X_3 = \frac{D_{8.2} - D_{1.6}}{2} = 10^{+0.01} - 9.75^{+0.026} = 0.25^{+0.01}_{-0.026} \text{ mm.}$$

Before calculating finally the executive technological size (the base size and the deviations are defined) it is necessary to check an opportunity of the solving of a size circuit with the previously accepted technological sizes. It is necessary that the sum of the tolerances of all component parts ($\sum TA_i$) should be less or equal to the tolerance of an initial (closing) link ($TA_\Delta$) (equation (5.1).

In our case:

$K_3 = \sum A_{inc} - \sum A_{red}$;

$K_3 = (A_{7.2} + A_{1.5}) - (X_3 + A_{7.1})$;

$TX_3$ = 0,036 mm

$TA_{7.2}$ = 0,062 mm

$TA_{1.5}$ =

$TA_{7.1}$ = 0,19 mm

$TK_3$ = 0,25 mm;

Check to see if the task is solvable:

$TK3 \geq \sum TA_i = TA_{7.2} + TA_{1.5} + TX_3 + TA_{7.1}$ = 0,062 + $TA_{1.5}$ + 0,036 + 0,19 =

$= TA_{1.5} + 0,288;$

$TA_{1.5} \le TK_3 – 0,288 = 0,25 – 0,288 = – 0,038$ mm

The task cannot be solved with these tolerances. Reduction of the tolerance of the component links is inexpedient, as the accuracy is high. Let's calculate the sum of the tolerances at new tolerance T $K_3$ = 0,6 mm:

$\sum T_{Ai} = TA_{7.2} + TA_{1.5} + TX_3 + TA_{7.1} = 0,062 + TA_{1.5} + 0,036 + 0,19 =$

$= TA_{1.5} + 0,288 \le TK_3;$

$TA_{1.5} \le 0,6 – 0,288 = 0,312$ mm

With this new tolerance, the task is solvable.

After that we write the equation of the size circuit, where in the left part we write the base size of a closing link (in our case $K_3$) (initial link is the name, as for this closing link it is required to maintain deviations given by the designer), and in the right part from the sum of the base sizes of increasing links the sum of the base sizes of reducing links is subtracted.

Therefore character of all making parts at first is determined. For this purpose one of the component links nearest to the closing link (in our case it can be $X_3$) is increased in the direction of the closing link. If thus the closing link is increased too, the considered component link is (on character) increasing. If the closing link on the contrary is decreased, the considered component link is reducing. Above a designation of a considered component link the pointer is put down: → (from left to right) - for increasing link; ← (on the right; on the left) - for reducing. After that we bypass the contour of the size circuit, putting down a pointer in the direction of bypassing, thus automatically defining character of all component links.

In our case we define at first the character of the link $A_{7.2}$ - it is an increasing link. Link $X_3$ - is reducing, $A_{1.5}$ - is increasing, $A_{7.1}$ - is reducing.

We write the equation of the size circuit:

$K_3 = (A_{7.2} + A_{1.5}) – (X_3 + A_{7.1}).$

We substitute numerical values of links:

$2 = (50 + A_{1.5}) – (0,25 + 50,5);$

We calculate the **base size** of the link $\mathbf{A_{1.5}}$:

$A_{1.5} = 2 – 50 + 50,5 + 0.25 = 2,75$ mm.

We accept the base value of the link $A_{1.5}$:  = 2,75 mm.

We write the equation of a size circuit for the **upper deviation** $\Delta^u_{K3}$ of the closing link $K_3$:

$\Delta^u_{K3} = (\Delta^u_{A7.2} + \Delta^u_{A1.5}) – (\Delta^l_{X3} – \Delta^l_{A7.1});$

We substitute numerical values of links deviations:

$+0.3 = (0 + \Delta^u_{A1.5}) – [(-0,026) + (-0.19)];$

We calculate the upper deviation of the link $A_{1.5}$:

$\Delta^u_{A1.5} = 0.3 – 0.19 – 0.026 = +0.084$ mm.

We accept the **upper deviation** of the link $\mathbf{A_{1.5}}$:  = +0.084 mm.

We write the equation of the size circuit for the **lower deviation** $\Delta^u_{K3}$ of the closing link, substitute numerical values of links deviations and calculate the lower deviation of the link $A_{1.5}$:

$\Delta^l_{K3} = (\Delta^l_{A7.2} + \Delta^l_{A1.5}) – (\Delta^u_{X3} + \Delta^u_{A7.1});$

$-0.3 = [(-0.062) + \Delta^{l}_{A1.5}] - [(+0.01) + 0]$;
$\Delta^{l}_{A1.5} = -0.3 + 0.062 + 0.01 = -0.228$ mm.
We accept the **lower deviation** of the link $\mathbf{A_{1.5}}$:  = -0.228 mm.
Hence, the technological size $A_{1.5}$ is necessary to maintain at boring of right chamfer in second operation: $A_{1.5} = 2.75^{+0.084}_{-0.228}$ mm.
We calculate the **tolerance** of the size $A_{1.5}$:
$T_{A1.5} = \Delta^{u}_{A1.5} - \Delta^{l}_{A1.5} = +0.084 - (-0.228) = 0.312$ mm.
We compare $TA_{1.5}$ with the previously determined tolerance ($TA_{1.5}$).

**5.2. Maintaining of chamfer size $K_4 = 3j_s14\ (\pm 0.25) \times 45^o$**

For maintaining size of right chamfer $K_4 = 3j_s16(\pm 0.25)\times 45^o$ in the general scheme (fig. 5.1) we select a size circuit (fig. 5.3), into which this design size $K_4$ enters, as it is not maintained directly.
In the size circuit we do as in previous case: we select the size $X_4$ which is the part of chamfer, removed after grinding of the hole Ø20H7 (fig. 5.1). As the chamfer is bored under the angle 45°, its size in the axial direction will be equal to the size in radial direction. Changing of chamfer size in a radial direction is defined as a difference of half of diameters between final grinding hole with H7 (technological size $A_{8.2}/2 = = Ø20H7\ (^{+0.021})\ /2$) and previous bored hole with H11 (technological size $A_{1.5}/2 = = Ø19.5H11\ (^{+0.13})\ /2$). The tolerances (deviations) thus also are divided half-and-half.

$X4 = \frac{D_{8.2} - D_{1.6}}{2} = 10^{+0.01} - 9.75^{+0.026} = 0.25^{+0.01}_{-0.026}$mm.

Before we calculate finally the executive technological size (the base size and the deviations are defined) it is necessary to check an opportunity of the solution of a size circuit with the previously accepted technological sizes. It is necessary that the sum of the tolerances of all component parts ($\sum TA_i$) should be less or equal to the tolerance of an initial (closing) link ($TA_\Delta$) (equation (5.1).
In our case:
$K_4 = \sum A_{inc} - \sum A_{red}$;
$K_4 = (A_{7.2} + A_{1.7}) - (X_4 + A_{7.1})$;
$TX_4 = 0{,}036$ mm
$TA_{7.2} = 0{,}062$ mm
$TA_{1.7} =$
$TA_{7.1} = 0{,}19$ mm
$TK_4 = 0{,}25$ mm;
Check to see if the task is solvable:
$TK_4 \geq \sum TA_i = TA_{7.2} + TA_{1.7} + TX_4 + TA_{7.1} = 0{,}062 + TA_{1.7} + 0{,}036 + 0{,}19 =$
$= TA_{1.7} + 0{,}288$;
$TA_{1.7} \leq TK_4 - 0{,}288 = 0{,}25 - 0{,}288 = -0{,}038$ mm
The task cannot be solved with these tolerances. Reduction of the tolerance of the component links is inexpedient, as the accuracy is high. Let's calculate the sum of the tolerances at new tolerance $T\,K_4 = 0{,}6$ mm:
$\sum T_{Ai} = TA_{7.2} + TA_{1.7} + TX_4 + TA_{7.1} = 0{,}062 + TA_{1.7} + 0{,}036 + 0{,}19 =$
$= TA_{1.7} + 0{,}288 \leq TK_4$;

$TA_{1.7} \leq 0,6 – 0,288 = 0,312$ mm
With this new tolerance, the task is solvable.
After that we write the equation of the size circuit, where in the left part we write the base size of a closing link (in our case $K_4$) (initial link is the name, as for this closing link it is required to maintain deviations given by the designer), and in the right part from the sum of the base sizes of increasing links the sum of the base sizes of reducing links is subtracted.
Therefore character of all making parts at first is determined. For this purpose one of the component links nearest to the closing link (in our case it can be $X_4$) is increased in the direction of the closing link. If thus the closing link is increased too, the considered component link is (on character) increasing. If the closing link on the contrary is decreased, the considered component link is reducing. Above a designation of a considered component link the pointer is put down: → (from left to right) - for increasing link; ← (on the right; on the left) - for reducing. After that we bypass the contour of the size circuit, putting down a pointer in the direction of bypassing, thus automatically defining character of all component links.
In our case we define at first the character of the link $A_{7.2}$ - it is an increasing link. Link *X4* - is reducing, $A_{1.7}$ - is increasing, $A_{7.1}$ - is reducing. We write the equation of the size circuit:
$K_4 = (A_{7.2} + A_{1.7}) – (X_4 + A_{7.1})$.
We substitute numerical values of links:
$3 = (50 + A_{1.7}) – (0,25 + 50,5)$;
We calculate the **base size** of the link $\mathbf{A_{1.7}}$:
$A_{1.7} = 3 – 50 + 50,5 + 0.25 = 3,75$ mm.
We accept the base value of the link $A_{1.7}$: = 3,75 mm.
We write the equation of a size circuit for the **upper deviation** $\Delta^u_{K4}$ of the closing link $K_4$:
$\Delta^u_{K4} = (\Delta^u_{A7.2} + \Delta^u_{A1.7}) – (\Delta^l_{X4} – \Delta^l_{A7.1})$;
We substitute numerical values of links deviations:
$+0.3 = (0 + \Delta^u_{A1.7}) – [(-0,026) + (-0.19)]$;
We calculate the upper deviation of the link $A_{1.7}$:
$\Delta^u_{A1.7} = 0.3 – 0.19 – 0.026 = +0.084$ mm.
We accept the **upper deviation** of the link $\mathbf{A_{1.7}}$: = +0.084 mm.
We write the equation of the size circuit for the **lower deviation** $\Delta^u_{K4}$ of the closing link, substitute numerical values of links deviations and calculate the lower deviation of the link $A_{1.7}$:
$\Delta^l_{K4} = (\Delta^l_{A7.2} + \Delta^l_{A1.7}) – (\Delta^u_{X4} + \Delta^u_{A7.1})$;
$-0.3 = [(-0.062) + \Delta^l_{A1.7}] – [(+0.01) + 0]$;
$\Delta^l_{A1.7} = -0.3 + 0.062 + 0.01 = -0.228$ mm.

We accept the **lower deviation** of the link $\mathbf{A_{1.7}}$: = -0.228 mm.
Hence, the technological size $A_{1.7}$ is necessary to maintain at boring of right chamfer in second operation: $A_{1.7} = 3.75^{+0.084}_{-0.228}$ mm.
We calculate the **tolerance** of the size $A_{1.7}$:

$T_{A1.7} = \Delta^{u}_{A1.7} - \Delta^{l}_{A1.7} = +0.084 - (-0.228) = 0.312$ mm.
We compare $TA_{1.7}$ with the previously determined tolerance ($TA_{1.7}$).

## 5.3. Maintaining size $К_2$ =20$j_s$14 (±0.26)

For maintaining size $К_2$ =20$j_s$16(±0.26) in the general scheme (fig. 5.1) we select a size circuit (fig. 5.4), into which this design size $К_2$ enters, as it is not maintained directly.
In the size circuit we have to obtain the right size for technological process $A_{3.2}$ to be able to maintain size $К_2$.
Before we calculate finally the executive technological size (the base size and the deviations are defined) it is necessary to check an opportunity of the solution of a size circuit with the previously accepted technological sizes. It is necessary that the sum of the tolerances of all component parts ($\sum TA_i$) should be less or equal to the tolerance of an initial (closing) link ($TA_\Delta$) (equation (5.1).
In our case:
$К_2 = \sum A_{inc} - \sum A_{red}$;
$К_2 = (A_{3.2} + A_{7.1}) - A_{2.2}$;
$TA_{3.2}$ =
$TA_{7.1}$ = 0,19 mm
$TA_{2.2}$ = 0.19 mm
$TК_2$ = 0,26 mm;
Check to see if the task is solvable:
$TК_2 \geq \sum TA_i = TA_{3.2} + TA_{7.1} + TA_{2.2} = TA_{3.2} + 0,19 + 0,19 =$
$= TA_{3.2} + 0,38$;
$TA_{3.2} \leq TК_2 - 0,38 = 0,26 - 0,38 = 0,14$ mm
With this tolerance the task is solvable.
After that we write the equation of the size circuit, where in the left part we write the base size of a closing link (in our case $К_2$) (initial link is the name, as for this closing link it is required to maintain deviations given by the designer), and in the right part from the sum of the base sizes of increasing links the sum of the base sizes of reducing links is subtracted.
Therefore character of all making parts at first is determined. For this purpose one of the component links nearest to the closing link (in our case it can be $A_{7.1}$) is increased in the direction of the closing link. If thus the closing link is increased too, the considered component link is (on character) increasing. If the closing link on the contrary is decreased, the considered component link is reducing. Above a designation of a considered component link the pointer is put down: → (from left to right) - for increasing link; ← (on the right; on the left) - for reducing. After that we bypass the contour of the size circuit, putting down a pointer in the direction of bypassing, thus automatically defining character of all component links.
In our case we define at first the character of the link $A_{3.2}$ - it is an increasing link. Link $A_{2.2}$ - is reducing, we write the equation of the size circuit:
$К_2 = (A_{3.2} + A_{7.1}) - A_{2.2}$
We substitute numerical values of links:

20 = ($A_{3.2}$ + 50.5) – 51;
We calculate the **base size** of the link $\mathbf{A_{3.2}}$:
$A_{3.2}$ = 20 – 50,5 + 51 = 20,5 mm.
We accept the base value of the link $A_{3.2}$:  = 20,5 mm.
We write the equation of a size circuit for the **upper deviation** $\Delta^{u}_{K2}$ of the closing link $K_2$:
$\Delta^{u}_{K2} = (\Delta^{u}_{A3.2} + \Delta^{u}_{A7.1}) – \Delta^{l}_{A2.2}$;
We substitute numerical values of links deviations:
$+0.26 = (\Delta^{u}_{A3.2} + 0) – (-0.19)$;
We calculate the upper deviation of the link $A_{3.2}$:
$\Delta^{u}_{A3.2}$  = 0.26 – 0.19 = +0.07 mm.
We accept the **upper deviation** of the link $\mathbf{A_{3.2}}$:  = +0.07 mm .
We write the equation of the size circuit for the **lower deviation** $\Delta^{u}_{K2}$ of the closing link, substitute numerical values of links deviations and calculate the lower deviation of the link $A_{3.2}$:
$\Delta^{l}_{K2} = (\Delta^{l}_{A3.2} + \Delta^{l}_{A7.1}) – \Delta^{u}_{A2.2}$;
$-0.26 = [\Delta^{l}_{A3.2} + (-0,19)] – 0$;
$\Delta^{l}_{A3.2}$ = -0.26 + 0.19 = -0.07 mm.
We accept the **lower deviation** of the link $\mathbf{A_{3.2}}$:  = -0.07 mm.
Hence, the technological size $A_{3.2}$ is necessary to maintain at drilling of hole $5H12^{(+0.12)}$) in third operation:  $A_{3.2} = 20.5^{+0.07}_{-0.07}$ mm.
We calculate the **tolerance** of the size $A_{3.2}$:
$T_{A3.2} = \Delta^{u}_{A3.2} - \Delta^{l}_{A3.2}$ = +0.07 – (-0.07) = 0.14 mm.

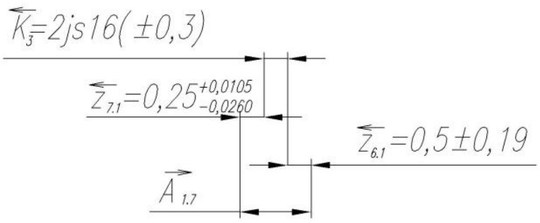


Fig. 5.7. Size circuit for calculation dimension $A_{1.7}$.

## 5.4. Maintaining size $K_5$ =5h14$^{(-0.3)}$

For maintaining size K5 =5h14$^{(-0.3)}$ in the general scheme (fig. 5.1) we select a size circuit (fig. 5.5), into which this design size $K_5$ enters, as it is not maintained directly.
In the size circuit we have to obtain the right size for technological process $A_{4.2.1}$ to be able to maintain size $K_5$.
Before we calculate finally the executive technological size (the base size and the deviations are defined) it is necessary to check an opportunity of the solution of a size circuit with the previously accepted technological sizes. It is necessary that the sum of the tolerances of all component parts ($\sum TA_i$) should be less or equal to the tolerance of an initial (closing) link ($TA_\Delta$) (equation (5.1).

In our case:
$K_5 = \sum A_{inc} - \sum A_{red}$;
$K_5 = (A_{7.2} + A_{4.2.1}) - A_{7.1}$;
$TA_{7.2} = 0.062$ mm
$TA_{4.2.1} =$
$TA_{7.1} = 0.19$ mm
$TK_5 = 0,3$ mm;
Check to see if the task is solvable:
$TK_5 \geq \sum TA_i = TA_{7.2} + TA_{7.1} + TA_{4.2.1} = 0,062 + TA_{4.2.1} + 0,19 =$
$= TA_{4.2.1} + 0,252$;
$TA_{4.2.1} \leq TK_5 - 0,252 = 0,3 - 0,252 = 0,048$ mm
With this tolerance the task is solvable.
After that we write the equation of the size circuit, where in the left part we write the base size of a closing link (in our case $K_5$) (initial link is the name, as for this closing link it is required to maintain deviations given by the designer), and in the right part from the sum of the base sizes of increasing links the sum of the base sizes of reducing links is subtracted.
Therefore character of all making parts at first is determined. For this purpose one of the component links nearest to the closing link (in our case it can be $A_{7.2}$) is increased in the direction of the closing link. If thus the closing link is increased too, the considered component link is (on character) increasing. If the closing link on the contrary is decreased, the considered component link is reducing. Above a designation of a considered component link the pointer is put down: → (from left to right) - for increasing link; ← (on the right; on the left) - for reducing. After that we bypass the contour of the size circuit, putting down a pointer in the direction of bypassing, thus automatically defining character of all component links.
In our case we define at first the character of the link $A_{4.2.1}$ - it is an increasing link. Link $A_{7.1}$ - is reducing, we write the equation of the size circuit:
$K_5 = (A_{7.2} + A_{4.2.1}) - A_{7.1}$
We substitute numerical values of links:
$5 = (50 + A_{4.2.1}) - 50.5$;
We calculate the **base size** of the link $\mathbf{A_{4.2.1}}$:
$A_{4.2.1} = 5 - 50,5 + 50 = 5,5$ mm.
We accept the base value of the link $A_{3.2}$:  = 5,5 mm.
We write the equation of a size circuit for the **upper deviation** $\Delta^u_{K5}$ of the closing link $K_5$:
$\Delta^u_{K5} = (\Delta^u_{A7.2} + \Delta^u_{A4.2.1}) - \Delta^l_{A7.1}$;
We substitute numerical values of links deviations:
$0 = (0 + \Delta^u_{A3.2}) - (-0.19)$;
We calculate the upper deviation of the link $A_{4.2.1}$:
$\Delta^u_{A4.2.1} = 0 - 0.19 = -0.19$ mm.
We accept the **upper deviation** of the link $\mathbf{A_{4.2.1}}$:  = -0.19 mm.

We write the equation of the size circuit for the **lower deviation** $\Delta^{u}_{K5}$ of the closing link, substitute numerical values of links deviations and calculate the lower deviation of the link $A_{4.2.1}$:

$\Delta^{l}_{K5} = (\Delta^{l}_{A7.2} + \Delta^{l}_{A4.2.1}) – \Delta^{u}_{A7.1}$;

$-0.48 = [(-0,062) + \Delta^{l}_{A4.2.1}] – 0$;

$\Delta^{l}_{A4.2.1} = -0.48 + 0.062 = -0.418$ mm.

We accept the **lower deviation** of the link $\mathbf{A_{4.2.1}}$:  = -0.418 mm.

Hence, the technological size $A_{4.2.1}$ is necessary to maintain at milling of key slot 15H15(+0.7) in fourth operation:  $A_{4.2.1} = 5.5^{-0.19}_{-0.42}$ mm.

We calculate the **tolerance** of the size $A_{4.2.1}$:

$T_{A4.2.1} = \Delta^{u}_{A4.2.1} - \Delta^{l}_{A4.2.1} = -0.19 – (-0.418) = 0.228$ mm.

# 6. CALCULATION of CUTTING MODES

Elements of cutting modes are nominated taking into account character of processing, type and sizes of the cutting tool, material of its cutting part, material and surface condition of a blank, type and condition of the equipment.

## 6.1. Calculation of cutting speed for turning of surface Ø30.9h11

Let's calculate modes of cutting at draft turning of an outside surface of the cartridge ***Ø30.9h11*** in the second operation. The size of the processed surface $d_i$ = ***= Ø30.9h11***. The size of a processable surface - $d_{i-1}$ = ***Ø34h16*** (diameter of forged blank). ***Previously*** we calculate the greatest depth of cutting $t_{max}$, if we remove all stock on rough (draft) processing for one pass (after 1 stroke):

$$t_{max} = (d_{(i-1)\,max} - d_{i\,min})/2 = = (34 - 30.74)/2 = 1.63 \text{ mm}.$$

The greatest depth of cutting is less than 4 mm [1, page 265], and it is possible to remove all stock for one pass. We ***accept the greatest depth of cutting*** $t_{max}$ ***= = 1.63*** mm. Other elements of a mode of cutting are usually established and calculated in the order which has been mentioned below.
Feed rate S is nominated by using machinist handbook [1, p. 266, tab. 11, p. 268, tab. 13 & 14]. At draft processing, choosing feed rate, it is necessary to check up durability of a cutter shank and carbide cutting plate, rigidity of a processable detail and durability of the feed rate mechanism of the machine tool. Feed rate S is usually limited by nose radius R and roughness of processed surface Ra [1, p. 268, tab. 14].
We choose a cutter under the recommendations. A cutter - through passage direct with a cutting plate from cemented carbide T15K6: 2100-01 17-T15K6.
The sizes of the cutter shank are 16×25 mm, diameter 30.9 mm , $s_a$ =0.4-0.5 mm/r [1, p. 266, tab. 11].
On the strength of throwaway-insert tool bit with thickness 4 mm , ultimate tensile stress $\sigma_{uts}$ of processed part material 40X is 1000 Mpa feed rate $s_b$ is caalculated as: $s_b$ =1.3×0.85×1=1.105 mm/r [1, p. 266, tab. 11].
On durability shank the large feed rate will sustain at rather small depth of cut t=1.63 mm. Therefore finally we choose feed rate proceeding from a required roughness of a surface for draft processing (Ra≤10 microns) and nose radius R =0.80 mm (at draft processing nose radius can be taken large, since the high accuracy is not required and elastic deformation of a cutter and a detail at the greater force $P_y$ does not play main role as at finish processing). Ultimate tensile stress $\sigma_{uts}$ of processed part material 40X is 1000 Mpa feed rate $s_b$ is caalculated as: $s_c$ =0.8×1.25 =1.0 mm/r [1, p. 268, tab. 14].
We determine feed rate S as minimal from $s_a$, $s_b$ and $s_c$: $s_a$ =0.4-0.5 mm/r ≈ $s_a$ =0.43 mm/r – is accepted feed rate.

It is possible to define cutting speed V, mpm, by several methods:

1) calculation by the formula;
2) using table data with the use of correction factors;
3) on the basis of the empirical data (used on the enterprise for the appropriate processable and cutting materials, geometry of the tool etc.)

Let's take advantage of calculation by the formula. For outside longitudinal and cross turning and boring the cutting speed V, mpm (meter per minute), is calculated by the formula:

$$V = \frac{C_V}{(T^m \cdot t^x \cdot s^y)} \cdot K_V , \qquad (6.1)$$

where: T - cutting tool life (period of work of the cutting tool before the wear). At draft processing in small-scale manufacture it is usually T=60 min.
The value of factor $C_V$ and parameters of a degree are given in tab. 17 [1, page 269, table 17]. For considered draft turning of an outside surface we accept that the depth of cut will be equal to the greatest depth of cut: $t = t_{max}$ = 1.63 mm. Factors and parameters of degrees are defined from tab. 17 [1]:

$$C_V=350; x=0.15; y=0.35; m=0.20.$$

$K_V$ - correction factor which takes into account geometry of cutting tool.

$$K_V = K_{Mv} \times K_{Иv} \times K_{Пv} \times K_{\varphi v} \times K_{\varphi 1v} \times K_{Rv} \times K_{Qv} \times K_{Ov} , \qquad (6.2)$$

where $K_{Mv} = K_g \times (750/\sigma_{uts})^{nv}$- is the factor which is take into account influence of quality of a processable material (durability) on cutting speed [1, page 261, table 1]. For steel 40X tensile strength (strength of stretching) $\sigma_{uts}=1000$ MPa, for cemented carbide $K_g$ = 0.95, $n_v$ =1 [1, page 262, table 2], therefore:
$K_{Mv} = K_g \times (750/\sigma_{uts})^{nv} = 0.95 \times (750/1000)^1 = 0.71$;
$K_{Иv}$ - factor taking into account material of a cutting part. For a cutting plate from a cemented carbide T15K6 $K_{Иv} =1$ [1, page 263, table 6];
$K_{Пv} =0.9$ - factor taking into account a condition of a surface of blank (hot rolled rod) [1, page 263, table 5];
$K_{\varphi v} = 0.7$ - factor taking into account geometrical parameters of a cutter (the main angle in the plan $\varphi=90^o$) [1, page 271, table 18];
$K_{\varphi 1v} = 1$ - factor taking into account geometrical parameters of a cutter (an auxiliary angle in the plan $\varphi_{1=}10^o$);
$K_{Rv} = 1$ - factor taking into account geometrical parameters of a cutter (nose radius R=2 mm of a cutter), for **cmented carbide** $K_{Rv} = 1$;

$$K_V = 0.71 \times 1 \times 0.9 \times 0,7 \times 1 \times 1 = 0,447 \approx 0.45.$$

$$V = \frac{C_V}{(T^m \cdot t^x \cdot s^y)} \cdot K_V = \frac{350}{(60^{0.2} \cdot 1.63^{0.15} \cdot 0.43^{0.35})} \cdot 0.45 = 128 \text{ mpm.}$$

We calculate number of revolutions of a spindle per 1 minute (frequency of spindle rotation) $n_{cal}$:

$$n_{cal} = \frac{1000 \cdot V}{\pi \cdot d_{\max}} = \frac{1000 \cdot 128}{\pi \cdot 30.9} = 1319 \text{ r/min}$$

where: $d_{max}$ - diameter of machined surface, mm.

In the technical passport of the machine tool we find the nearest smaller number of revolutions of a spindle (smaller - since even at insignificant increasing of cutting speed can result an essential reduction of cutting tool life *T*): $n_{pas}$ = 1250 rev/min. We calculate the ***real*** (specified or corrected) ***cutting speed*** at the accepted number of revolutions of a spindle:

$$V = \frac{\pi \cdot d \cdot n_{pas}}{1000}, \text{ mpm.} \qquad (6.6)$$

In our case the real speed of cutting Nr:

$$V_{\partial} = \frac{\pi \cdot 30.9 \cdot 1250}{1000} = 121 \text{ mpm.}$$

We accept $n_{acc}$= 1250 r/min.

It is accepted to split the force of cutting P on making (component) forces which are directed on axes of coordinates of the machine tool (Pz, Py, Px) to make calculations easer.
For outside longitudinal turning [1, page 271]:

$$P_{z,y,x} = C_P \times t^x \times s^y \times V^n \times K_P, \text{ [N]}, \qquad (6.3)$$

where $C_P$ - factor depending on a processable and cutting material; $K_P$ - correction factor.

$$K_P = K_{Mp} \times K_{\varphi p} \times K_{\gamma p} \times K_{\lambda p} \times K_{Rp}, \qquad (6.4)$$

where $K_{Mp}$ - factor taking into account influence of quality of a processable material (durability) on force of cutting. For steel 40X strength on a stretching is $\sigma_{UTS}$=1000MPa, therefore $K_{Mp} = (\sigma_{uts} / 750)^{np} = (1000 / 750)^{0.75} = 1.24$
[1, page 264, table 9];

$K_{\varphi p}$ - factor taking into account influence of the main angle in the plan $\varphi$ on a force of cutting, $K_{\varphi p}$ =0.89 [1, page 275, table 23];
$K_{\gamma p}$- factor taking into account influence of the main forward angle in main crossection plane $\gamma$ (rake angle) on force of cutting, $\gamma=7°$; $K_{\gamma p}$ =1.0 [1, page 275, table 23];
$K_{\lambda p}$ - factor taking into account influence of an inclination main cutting edge angle $\lambda$ on force of cutting, $\lambda=0°$; $K_{\lambda p}$ =1;
$K_{Rp}$ - factor taking into account influence of cutter nose radius R on force of cutting, R=2 mm, $K_{Rp}$ =1;

For considered draft turning of an outside surface ***Ø30.9h11*** in the second operation we accept that depth of cut $t$ will be equal to the greatest depth of cut $t_{max}$: $t = t_{max}$ = 1.63 mm. Factors and parameters of degrees found in tab. 22 [1, page 273, table 22] we write in tab. 6.1.

Table 6.1. Calculation of cutting component forces at rough turning ***Ø30.8h11***

| Compo-nents | $C_P$ | $x$ | $y$ | $n$ | $K_{Mp}$ | $K_{\varphi p}$ | $K_{\gamma p}$ | $K_{\lambda p}$ | $K_{Rp}$ | $K_P$ | $P_{z,y,x}$, N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $P_z$ | 300 | 1 | 0.75 | -0.15 | 1.24 | 0.89 | 1 | 1 | 1 | 1.1 | 1425.4 |

$P_z = 10 \times 300 \times 1.63^1 \times 0.43^{0.75} \times 121^{-0.15} \times 1.1 = 1425.4$ N;

The ***cutting power*** is calculated by the formula:

$$N = \frac{P_z \cdot V}{1020 \cdot 60}, \text{ [kW]} \qquad (6.5)$$

where $P_z$ - tangential component of cutting force (conterminous on a direction with a vector of cutting speed ), N; V - cutting speed, mpm.

In our case at rough turning of an outside surface ***Ø30.8h11***:

$$N_{cutting} = \frac{1425.4 \cdot 121}{1020 \cdot 60} = 2.98 \text{ kW.}$$

Power of machine tool (equipment) is calculated:
$N_m = k \times N_{cutting} = (1.5 – 2.5) \times 2.98 = 2 \times 2.98 = 5.96$ kW

## 6.2. Calculation of cutting modes, forces and power in drilling Ø4H12

We choose the cutting tool by recommendations: a drill Ø4 mm GOST 10902-64; a material of a cutting part - high speed steel (HSS) P6M5, point angle 2φ = 118º.

Depth of cut at drilling t = 0.5·D = 0.5·4 = 2 mm.

### 6.2.1. Calculation of cutting modes and forces in drilling Ø4H14 by the calculation method

Maximal feed rate is choused in accordance with rigidness of drill (diameter of drill Ø4 mm ), cutting tool material (HSS P6M5), machined material (steel 40X) with hardness HB 200-220 , surface roughness (Ra<10 μm) and recommendations which are given in tab. 27 [1, page 277, table 25]: S = 0.06-0.07 mmpr.

The **cutting speed** at drilling is calculated by the formula:

$$V = \frac{C_V \cdot D^q}{(T^m \cdot s^y)} \cdot K_V \quad , \qquad (6.6)$$

where: T - cutting tool life (at drilling T=45 minutes [1, page 415]).

For **redrilling** or **core-drilling**:

$$V = \frac{C_V \cdot D^q}{(T^m \cdot t^x \cdot s^y)} \cdot K_V \qquad (6.7)$$

Cutting tool life T of drill 4 mm is 15 minutes [1, page 279, table 30]

Values of factor $C_V$ and parameters of a degree for a drill from HSS and drilling in processable constructional steel (steel 40X) are given in tab. 8 [1, page 278, table 28]: $C_V=7.0;\ q_v = 0.4;\quad y=0.7;\ m=0.20.$

$K_V$ - correction factor:

$$K_V = K_{Mv} \times K_{Иv \quad lv}, \qquad (6.8)$$

where $K_{Mv} = K_g \times (750/\sigma_{uts})^{nv}$- is the factor which is taken into account on the influence of quality of a machined material (durability) on cutting speed [1, page 261, table 1]. For steel 40X tensile strength (strength of stretching) $\sigma_{uts}=1000$ MPa, for high speed steel $K_g$ = 0.85, $n_v$ =0.9 [1, page 262, table 2], therefore:

$K_{Mv} = K_g \times (750/\sigma_{uts})^{nv} = 0.85 \times (750/1000)^{0.9} = 0.65$;

$K_{Иv}$ - factor which taking into account material of a cutting part. For a drill from HSS P6M5 $K_{Иv}$ =0.3 [1, page 436];

$K_{lv}$ =0.4 - factor which is taken into account depth of a drilled hole (L<8D) (L =30, D = 4 mm, L/D = 30/4 = 8) [1, page 280, table 31] .

$$K_V = 0.65 \times 0.4 \times 1 = 0.26.$$

$$V = \frac{C_V \cdot D^q}{(T^m \cdot s^y)} \cdot K_V = \frac{7 \cdot 4^{0.4}}{(15^{0.2} \cdot 0.06^{0.5})} \cdot 0.26 = 12.2 \text{ m/m.}$$

The **torsion moment** in drilling is calculated by the formula [1, p.277] :

$$M_c = 10 \cdot C_M \cdot D^q \cdot S^y \cdot K_p \text{ , } [N \cdot m] \qquad (6.9)$$

where: $C_M$·=0.0345 - factor which is taking into account machinability of a material (in our case it is unquenched steel 40X) [1, p.281, table 32]; $q = 2; y = 0,8; K_p = K_m = (\sigma_{uts}/750)^n$ . [1, p.264, table 9];
$K_p = (\sigma_{uts}/750)^n = (1000/750)^{0.75} = 1.23$

$$M = 10 \cdot 0.0345 \cdot 4^2 \cdot 0.06^{0.8} \cdot 1.23 = 0.71 \ N \cdot m.$$

The **axial force** in drilling is calculated by the formula [1, p.277] :

$$P_{ax} = 10 \cdot C_P \cdot D^q \cdot S^y \cdot K_p \text{ , } [N] \qquad (6.10)$$

where: $C_P$ = 68 - factor which is taking into account durability of a processable material (in our case - unquenched steel 40X) [1, p.281, table 32]; $q_p = 1; y_P = 0,7;$ $K_p = K_m = (\sigma_{uts}/750)^n$ . [1, p.264, table 9];
$K_p = (\sigma_{uts}/750)^n = (1000/750)^{0.75} = 1.23$.

$$P_{ax} = 68 \cdot 4^1 \cdot 0.43^{0,7} \cdot 1.23 = 185.3 \ N.$$

For calculation of cutting power it is necessary to know **frequency of a spindle rotation n**. We calculate number of revolutions of a spindle $n_{cal}$:

$$n_{cal} = \frac{1000 \cdot V}{\pi \cdot d_{max}} = \frac{1000 \cdot 12.2}{\pi \cdot 4} = 970.9 \text{ rpm,}$$

where $d_{max}$ – the greatest diameter of working cutting edge relatively of axis of the rotating tool, mm.

In the technical passport of the machine tool we find the nearest smaller number of revolutions of a spindle (smaller - since even at insignificant increasing of cutting speed can result an essential reduction of cutting tool life *T*): $n_{pas}$ = = 1000 rpm. We calculate the ***real*** (specified or corrected) ***cutting speed*** at the accepted number of revolutions of a spindle by the formula (6.6):

$$V_r = \frac{\pi \cdot d \cdot n_{pas}}{1000} = \frac{3.14 \cdot 4 \cdot 1000}{1000} = 12.6 \text{ mpm.}$$

**Cutting power** at drilling Ø4H14 is calculated by the formula:

$$N = \frac{M \cdot n}{9750} = \frac{0.71 \cdot 1000}{9750} = 0.073 \text{ kW} \qquad (6.11)$$

### 6.2.2. Calculation of cutting modes and forces in drilling Ø4H14 by the table method

We choose the tool under the recommendations [2, page 450]: a drill Ø5 mm GOST 10902-64; a material of a cutting part - HSS P6M5, point angle 2φ = 118º.

Depth of cut at drilling t = 0.5·D = 0.5·5 = 2.5 mm. Using a tabulared method, we determine cutting modes. Maximal feed rate is determined by the recommendations [3, page 253]: group of feed rate -1, $S_r$ = = 0.1 mmpr.

Cutting speed at drilling is determined by the recommendations [3, page 245]:

$$V = V_{tab} \cdot K_1 \cdot K_2\, K_3, \qquad (6.12)$$

where $K_1$=1.3; $K_2$=1.15; $K_3$=1. $V_{tab}$= 24 mpm [3, page 245]. Then:

$$V = V_{tab} \cdot K_1 \cdot K_2\, K_3 = 24 \cdot 1.3 \cdot 1.15 \cdot 1 = 35.88 \text{ mpm.}$$

We calculate number of revolutions of a spindle $n_{cal}$:

$$n_{cal} = \frac{1000 \cdot V}{\pi \cdot d_{\max}} = \frac{1000 \cdot 35.88}{\pi \cdot 5} = 2285 \text{ rpm.}$$

In the technical passport of the machine tool we find the nearest smaller number of a spindle revolutions: $n_{pas}$ = 2000 rpm. We correct the real cutting speed at the accepted number of revolutions of a spindle by the formula (6.6):

$$V_r = \frac{\pi \cdot d \cdot n_{pas}}{1000} = \frac{3.14 \cdot 5 \cdot 2000}{1000} = 31.4 \text{ mpm.}$$

We calculate axial force of cutting:

$$P_{ax} = P_{tab} \cdot K_p = 110 \cdot 0.75 = 82.5 \text{ kg.} = 825 \text{ N} \qquad (6.13)$$

We calculate cutting power:

$$N = N_{tab} \cdot K_p \cdot n = 0.2 \cdot 0.75 \cdot 2000 = 300 \text{ W} = 0.3 \text{ kW.} \qquad (6.14)$$

Required power of the electric motor of the machine tool:

$$N_{mach} > N \cdot 1.12 = 0.3 \cdot 1.12 = 0.336 \text{ kW.}$$

### 6.3. Calculation of cutting modes and power in saw (disk) milling of face end in first operation

Initial data: diameter of cut off rod is 35 mm for length 56 mm, steel 40X.
Saw milling cutter is made from HSS steel P6M5 [1, table 86, p. 184], diameter 100 mm, execution 3, quantity of teeth is 40, width is 3 mm, hole diameter is 32 mm [GOST 2679-73]. Feed rate per tooth is $S_z$=0,05 mm/tooth [1, table 33, p. 283]. Cutting speed is calculated by formula

$$V = \frac{C_V \cdot D^q}{(T^m \cdot t^x \cdot s_z^{\ y} \cdot B^u \cdot z^p)} \cdot K_V \quad , \qquad (6.15)$$

where: T – cutting tool life (for saw mills with diameter from 90 to 150 mm T=120 minutes [1, table 40, p. 290].

Coefficient $C_V$ and exponents we determine for HSS saw mills in cutting with cutting fluid in table 39 [1, table. 39, p. 286]:

$C_V=53;\ q = 0.25;\ x=0.3;\ y=0.2;\ u=0,2;\ p=0,1;\ m=0.2.$

$K_V$ - coefficient for machined material :

$$K_V = K_{Mv} \times K_{sv} \times K_{tv}\ , \qquad (6.16)$$

where $K_{Mv} = K_g \times (750/\sigma_{uts})^{nv}$- is the factor which is taken into account on the influence of quality of a machined material (durability) on cutting speed [1, page 261, table 1]. For steel 40X tensile strength $\sigma_{uts}=1000$ MPa, for high speed steel $K_g$ = 0.85, $n_v$ =0.9 [1, page 262, table 2], therefore:

$K_{Mv} = K_g \times (750/\sigma_{uts})^{nv} = 0.85 \times (750/1000)^{0.9} = 0.65$;

$K_{sv}$ - factor which taking into account quality of workpiece surface [1, page 436]. $K_{sv}$ =1;

$K_{tv}$ - factor which taking into account material of a milling cutter. For a mill, made from HSS P6M5, $K_{tv}$ =1 [1, page 436];

$$K_V = 0.65 \times 1 \times 0,9 = 0,585.$$

$$V = \frac{C_V \cdot D^q}{(T^m \cdot t^x \cdot s_z^{\ y} \cdot B^u \cdot z^p)} \cdot K_V = \frac{53 \cdot 100^{0.3}}{(120^{0.2} \cdot 35^{0.3} \cdot 0.05^{0.2} \cdot 3^{0,2} \cdot 40^{0,1})} \cdot 0{,}59 = 16.83 \text{ m/min.}$$

Quantity of mill's revolution $n_{calc}$:

$$n_{calc} = \frac{1000 \cdot V}{\pi \cdot d} = \frac{1000 \cdot 16.83}{3.14 \cdot 100} = 53{,}6 \text{ r/min,}$$

где d – diameter of mill, mm.

Accept $n_{mill}$= 63 r/min.

## 6.4. Calculation of cutting modes and power at round grinding Ø30g6

We choose the cutting tool by recommendations [1, pages 242, 245, 246, 249, 250, 252 - 254]:

1. The **type of abrasive** is 14A (normal aluminum oxide) [1, pages 242] or A (Alundum) in accordance with American terminology. Aluminum oxide grains or crystals, although not the hardest artificial abrasive, are tough and are best for grinding materials of high-tensile strength. They are used to grind carbon steels, alloy steels, soft or hard steels, cast-alloy cutting tools, wrought iron, and tough bronze.
2. The **grain size** - 25 (fine grinding of parts with Ra<0.8 μm and with grade of tolerance 6) [1, page 247]. Grain refers to the size of the abrasive particles used in the manufacture of the grinding wheel. The grain size is determined by the **mesh number** of the finest screen through which the grain will pass. For example, a 36-grain wheel is one made of particles of abrasive which just pass through a 36-mesh screen, but which will be retained on a 46-mesh screen, the next finer screen. (A 36-mesh screen has 36 openings each lineal 25.4 mm, or 200 openings per square centimeter. Grain numbers are sometimes called **grit numbers**.
3. The **bond** material is K2 (S2 in accordance with American terminology) (silicate-bonded wheels which are used for grinding steel parts) [1, page 247]. The **bond** is the material which holds the abrasive grains together to form the grinding wheel. As the grains get dull, pressure on the wheel causes the bond to break down and release the dull grains, thus exposing new sharp grains. The bond holds the individual grain in much the same manner as a tool holder holds a tool bit. There are five basic types of bonds used in grinding wheels: **vitrified, silicate, rubber, shellac, and resinoid**. Additional modifications of these five materials are also produced by some manufacturers. Approximately 75% of all wheels are made with **vitrified** or a modified vitrified bond. Vitrified-bond wheels are strong, porous, and are not affected by rapid changes in temperature, oils, acid, or water. These wheels are uniform in structure, free from hard spots, and hold their form well. The bond is formed when special clays are mixed with abrasive grains and heated to high temperatures. The mixture forms a molten glass which cements the grains together. Wheels bonded with **silicate** (silicate of soda) are known as silicate- or semi-vitrified-bond wheels. Silicate-bonded wheels release the grains more readily than vitrified bond. Hence, the wheel is softer and it breaks down more readily, thereby exposing new sharp grains. Silicate-bonded wheels are used for grinding steel parts, edge tools, drills, reamers, milling cutters, and similar tools.
4. The **hardness of grinding wheel** is CM2 (which is rated between soft and medium) [4, page 59] or H grade in accordance with American

terminology. Wheels from which the grit or abrasive is readily torn are termed **soft grade**. Conversely, wheels that do not readily release the grain are called **hard grade**. **Hard-grade** wheels generally are used **for grinding soft** metals such as mild steel. **Soft-grade** wheels generally are used **for grinding hard** metals such as high-carbon steel. It should be remembered that the term hard as used with respect to grinding wheels has no relationship to the hardness of the abrasive, but rather to the ease or difficulty with which the worn particles of the abrasive are torn from the face of the wheel. With a given bond material, it is the amount of bond which determines the hardness or softness of the wheel - the more bond material, the harder the wheel. The grade of grinding wheels is designated by letters of the alphabet, A being the softest and Z the hardest, [4, table 22-2].

5. The **structure** of a grinding wheel is 6 (middle density). The **structure** of a grinding wheel refers to the spacing between the grains, or the density of the wheel. Grains which are very closely spaced are denser or close, while grains which are wider apart are less dense or open. The structure of a wheel is rated with numbers from 1 (dense) to 15 (open). The rate of metal removal usually is greater for wheels with an open structure. However, those with dense structure usually produce a finer finish.

The marking on the grinding wheel is ЧК 250-25-50 14А 25 СМ2 6 К2/ППС 40 15 in accordance with Russian terminology. This marking indicates that the type of grinding wheel is bowl-plate shape (ЧК), external diameter is 250 mm, height (width) is 25 mm, diameter of hole is 50 mm; type of abrasive is type 14A (normal aluminum oxide); with a 25 medium grain size; with CM2 grade (which is rated between soft and medium); structure 6 (middle density); bond type K2 (which is silicate-bonded); and ППС 40 15 represents the manufacturer's mark for the specific type of silicate bond (the porosity used material is polystyrene ППС with 40 grain size and space containing in abrasive weight is 15 percent. A grinding wheel of this type will do a good job in surface-grinding hardened carbon steel.

The standard system for marking wheels adopted by the American Standards Association includes six parts in sequence, as listed across the top of Table 22-2 [4]. Note that the prefix to item one in the sequence is optional for each manufacturer. For example, where several types of a given abrasive are available, such as several variations of aluminum oxide, the prefix number indicates the exact type of aluminum oxide. Also note that items four and six in the sequence are optional with the manufacturer.

Grinding wheel markings adopted by the American Standards Association is T1 250-25-50 25A -H8SBE [4, page 59]. This marking indicates that the type-number (shape) of grinding wheel is 1 (with straight profile) [1, page 56], the diameter of grinding wheel is 250 mm, the diameter of grinding wheel hole is 50 mm (the diameter of the spindle hole), the height (the width) of grinding wheel is

25 mm, the abrasive is type 25 Alundum with a 25 medium grain size; with H grade (which is rated between soft and medium); structure 8 (middle density); bond type S (which is silicate); and BE represents the manufacturer's mark for the specific type of silicate bond. A grinding wheel of this type will do a good job in surface-grinding hardened carbon steel.

Cutting modes **for feed rate for double pass** are chosen by recommendations [1, pages 301]:

1.Cutting speed V= 30...35 mps (tangential speed of grinding wheel)
$n_{gw}$= 60000×V/(π×$d_{gw}$) = 60000×30/(π×250) = 2293 ≈ 2500 rpm.
2. Tangential speed of a part $V_p$ = 20...30 mpm; $n_p = 1000 \times V/(\pi \times d_p)$ =
= $1000 \times 20/(\pi \times 30)$ = 212 ≈ 250 rpm; corrected speed of part $V_{p\ cor} = \pi \times d_p \times n_p/1000$ = = $3.14 \times 30 \times 250/1000$ = 23.6 mpm.
3. Depth of cut (of grinding) t = 0.015...0.05 mm. We accept t = 0.03 mm.
4. Lengthwise feed rate S = (0.3...0.7) ×B = 0.5×25 = 12.5 mmpr, where B is the length of working part of the wheel.
5. Quantity of passes is calculated by the formula:

$$i = 2 \cdot z_{max\ i} / 2 \cdot t = z_{max\ i} / t, \qquad (6.17)$$

where $2 \cdot z_{max}$ is maximal stock in considered technological transition. Maximal stock is calculated: $2 \cdot z_{max\ i}$ = $d_{(i-1)\ max}$ - $d_{i\ min}$ = 30.1 – 29.98 = 0.12 mm.
$d_{i-1}$ =Ø30.1h9($_{-0.062}$), $d_i$ =Ø30g6($^{-0.007}_{-0.02}$).

$$i = 2 \cdot z_{max} / 2 \cdot t = 0.12/2 \cdot 0.03 = 2.$$

We accept ***i* = 3**, because we are to add one pass for reducing depth of cut in last pass and reducing errors of grinding which are appeared due to elastic recovering of part and machine tool mechanism (errors of size, out of roundness and cylindrical, roughness of surface). We are take into account time for returning grinding well in right side for cross feed of well (idle passes). That is why whole quantity of passes is equal 6 (3 of working and 3 of idle passes).

The **cutting power** for feed rate for double pass at round grinding Ø30h7 is calculated by the formula:

$$N = C_N \times V_p^r \times t^x \times s^y \times d^q , \qquad (6.18)$$

where $C_N$ = 2.65; $r$ = 0.5; $x$ = 0.5; $y$ = 0.55; $q$ = 0 [4, page 301].

$$N = C_N \times V_p^r \times t^x \times s^y \times d^q = 2.65 \times 23.6^{0.5} \times 0.03^{0.5} \times 12.5^{0.55} \times 30^0 = 3.46 \text{ kW}.$$

Grinding machine is chosen in accordance with the type of work (grinding of external cylindrical surface), the diameter of processable part (Ø30 mm) and the length (L=51 mm), the required power of grinding driver (*N*=3.46 kW). We choose plain grinding machine 3M150 [1, page 29] with maximal diameter of processable part Ø100 mm but recommended diameter of external grinding is Ø10…45 mm, maximal length of grinding is 340 mm, maximal longitudinal moving of grinding table with headstock is 400 mm, frequency of blank spindle rotation is stepless (with variable-speed mechanism) from 100 to 1000 rpm, frequency of grinding spindle rotation is 2350 and 1670 rpm for external grinding, maximal diameter of grinding well is 400 mm, maximal height of grinding well is 40 mm, maximal cross moving of grinding tailstock is 80 mm with resolution 0.0005 mm, power of grinding driver is 4 kW, diameter of grinding well hole is 50 mm.

## 6.6. Calculation of cutting modes and forces at milling key slot 8H9

We choose the cutting tool by recommendations [2, page 450]: **two-flute** single-end milling cutter Ø8 mm from solid cutter made of one piece of high-speed steel P6M5. Two-flute end mills have only two teeth. The end teeth are designed so that they can cut to the center of the mill. Therefore, two-flute end mills may be fed into the work like a drill; they then may be fed lengthwise to form a slot.

Depth of cut at milling of key slot t = D = 8 mm. Maximal width is used about b ≈ 0.5×*D* = 0.5×8 =4 mm,

Maximal feed rate for one teeth $S_z$ is chosen in accordance with rigidness of mill (diameter of mill Ø8 mm), cutting tool material (HSS P6M5), processable material (steel 40X), surface roughness of slot sides (Ra < 6.3 µm) and recommendations which are given in tab. 38 [1, page 286] for two-flute mills (quantity of teeth z = 2): axial feed rate $S_{z\,ax}$ = 0.007 mm per tooth, lengthwise feed rate $S_{z\,lw}$ = 0.022 mm per tooth.

The **cutting speed** at milling is calculated by the formula:

$$V = \frac{C_V \cdot D^q}{(T^m \cdot t^x \cdot s_z^{\;y} \cdot B^u \cdot z^p)} \cdot K_V \quad , \qquad (6.19)$$

Where: T - cutting tool life (at key slot milling T=80 minutes, tab. 40 [1, page 290]).

Values of factor $C_V$ and parameters of a degree for a two-flute mills from HSS and milling with cooling in processable constructional steel (steel 40X) are given in tab. 39 [1, page 286]:

$C_V=46.7$; $q = 0.45$; $x=0.5$; $y=0.5$; $u=0.1$; $p=0.1$; $m=0.3$.

$K_V$ - correction factor:

$$K_V = K_{Mv} \times K_{Пv} \times K_{Иv} \, , \qquad (6.20)$$

where $K_{Mv} = 75/\sigma_в$ - factor which is taking into account influence of quality of a processable material (durability) on cutting speed. For steel 40X strength of a stretching $\sigma_в=75$ kg / mm$^2$, therefore $K_{Mv} = 75/\sigma_в = = 75/75 =1$;
$K_{Иv}$ - factor which taking into account material of a cutting part. For a cutting tool from HSS P6M5 $K_{Иv}$ =1 [1, page 263, tab.6];
$K_{Пv}$ =1 - factor which is taking into account a blank surface condition [1, page 263, tab.5].

$$K_V = 1 \times 1 \times 1 = 1.$$

$$V = \frac{C_V \cdot D^q}{(T^m \cdot t^x \cdot s_z^{\ y} \cdot B^u \cdot z^p)} \cdot K_V = \frac{46.7 \cdot 8^{0.45}}{(80^{0.3} \cdot 8^{0.5} \cdot 0.022^{0.5} \cdot 6^{0.1} \cdot 2^{0.1})} \cdot 1 = 59.5 \text{ mpm.}$$

We calculate number of revolutions of a spindle $n_{cal}$:

$$n_{cal} = \frac{1000 \cdot V}{\pi \cdot d_{mill}} = \frac{1000 \cdot 59.5}{3.14 \cdot 8} = 2368 \text{ rpm,}$$

Where $d_{mill}$ –diameter of mill, mm.

In the technical passport of the machine tool we look for the nearest number of revolutions of the spindle to our calculated figure (should be lesser because even an insignificant increment in the cutting speed can result in an evident reduction in cutting tool life *T*): $a_{ccepted}$ = 1000 rpm because our milling machine ФУ 521 has 1000 rpm as its highest which makes 1000 rpm the nearest number of revolution of the spindle to our $n_{cal.}$. We calculate the ***real*** (specified or corrected) ***cutting speed*** at the accepted number of revolutions of a spindle by the formula (7.6):

$$V_r = \frac{\pi \cdot d \cdot n_{accepted}}{1000} = \frac{3.14 \cdot 8 \cdot 1000}{1000} = 25.12 \text{ mpm.}$$

Calculation of **tangential component of cutting force** $P_z$ [ N], at milling is done by the formula

$$P_z = \frac{10 \cdot C_p \cdot t^x \cdot s_z^y \cdot B^u \cdot z}{D^q \cdot n^w} \cdot K_{mp} . \qquad (6.21)$$

Values of factor $C_V$ and parameters of the degree for an end mill from HSS and milling in process able constructional steel (steel 40X) are given in tab. 41 [1, page 291]:

$$C_p=68.2; \ q = 0.86; \ x=0.86; \ y=0.72; \ u=1; \ w=0.$$

$K_{mp}$ - correction factor:

$$K_{mp} = K_{Mp} \times K_{Пp} \times K_{Иp} , \qquad (6.22)$$

where $K_{Mp} = 75/\sigma_в$ - factor which is taking into account influence of quality of a processable material (durability) on cutting speed. For steel 40X strength of a stretching $\sigma_в=75$ kg / mm$^2$, therefore $K_{Mv} = 75/\sigma_в = = 75/75 =1$;

$K_{Ир}$ - factor which taking into account material of a cutting part. For a cutting tool from HSS P6M5 $K_{Ир}$ =1 [1, page 263, tab.6];
$K_{Пр}$ =1 - factor which is taking into account a blank surface condition [1, page 263, tab.5].

$$K_V = 1 \times 1 \times 1 = 1.$$

$$P_z = \frac{10 \cdot C_p \cdot t^x \cdot s_z^y \cdot B^u \cdot z}{D^q \cdot n^w} \cdot K_{mp} = \frac{10 \cdot 68.2 \cdot 8^{0.86} \cdot 0.022^{0.72} \cdot 6^1 \cdot 2}{8^{0.86} \cdot 1000^0} \cdot 1 = 524 \text{ [N]}.$$

Other components of cutting force are calculated by the ratios [1, page 292, table 42]:

$P_h : P_z = 0.3 – 0.4$; $P_h = P_z \cdot 0.4 = 524 \cdot 0.4 = 209.6$ [N];

$P_v : P_z = 0.85 – 0.95$; $P_v = P_z \cdot 0.95 = 524 \cdot 0.95 = 497.8$ [N];

$P_y : P_z = 0.3 – 0.4$; $P_y = P_z \cdot 0.4 = 524 \cdot 0.4 = 209.6$ [N];

$P_x : P_z = 0.5 – 0.55$; $P_x = P_z \cdot 0.55 = 524 \cdot 0.55 = 288.2$ [N];

The ***cutting power*** at milling key slot 8H9 **is** calculated by the formula (6.5):

$$N = \frac{P_z \cdot V}{1020 \cdot 60} = \frac{524 \cdot 25.12}{1020 \cdot 60} = 0.215 \text{ kW}.$$

Where $P_z$ - tangential component of cutting force, N
V - Cutting speed, mpm.

## 7. TECHNICAL FIXING of LABOURIOUSNESS

In small-scale manufacture it is necessary to know the norm of **floor-to-floor calculated time** $T_{fc}$ - time of detail manufacturing on one technological operation taking into account time for preparation of machine tool, cutting tools and attachment for the work. This time is determined by the formula:

$$T_{fc} = T_f + \frac{T_p}{n_s}, \text{ min,} \qquad (7.1)$$

where $T_p$ is a time for preparation of machine tool, cutting tools and attachment for the work; $n_s$ is a set of detail for manufacturing in one set.

The norm of **floor-to-floor time** $T_f$ is a piece time, or time of part manufacturing on one technological operation taking into account time for removing of chip and auxiliary time for operate with machine tool, but do not taking into account time for preparation of machine tool, cutting tools and attachment for the work. This time is determined by the formula:

$$T_f = T_{op} + T_s + T_r, \text{ min,} \qquad (7.2)$$

where: $T_s$ is a time for service of machine tool (oiling, brushing, changing and sharpening of worn out cutters and etc.); $T_r$ is time for the rest. Generally Ts is equal 5% from $T_{op}$ , $T_r$ is equal 6% from $T_{op}$ , but sometimes $T_s + T_r = 15\%$ from $T_{op}$. Further we will calculate $T_s = 0.05 \cdot T_{op}$, $T_r = 0.06 \cdot T_{op}$,

The norm of **operative time** $T_{op}$ is determined by the formula:

$$T_{op} = T_d + T_{aux}, \text{ min.} \qquad (7.3)$$

The norm of **direct time** $T_d$ is time when the work feed rate is turn on for removing of chip from a surface. This time include the time for removing of chip from a surface and also the time for **under cutting** on the length $l_{uc}$ (under running) and **over cutting** on the length $l_{oc}$ (over running). Direct time is determined by the formula:

$$T_d = \frac{L}{n \cdot S_r}, \text{ min,} \qquad (7.4)$$

where: $L$ is a length of feed rate running, mm; $n$ is quantity of revolutions of spindle in one minute, rpm; $S_r$ is a feed rate, mmpr. For the milling and grinding operations generally feed rate for one minute is used for maintaining of feed rate of table:

$$S_m = S_r \cdot n, \text{ mmpm.} \qquad (7.5)$$

Feed rate for one tooth $S_z$ , mm per teeth, is written in handbook for milling operation. Minute feed rate can be calculated by the formula:

$$S_r = S_z \cdot z, \text{ mmpr,} \qquad (7.6)$$

where z is a quantity of teeth of milling cutter.

The **auxiliary time** $T_{aux}$ is calculated by the formula

$$T_{aux} = T_l + T_c + T_o + T_m, \text{ min.} \qquad (7.7)$$

where: $T_l$ - is time for maintaining and fixing (loading) and unloading of a blank; $T_c$ - is time for clamping of a blank; $T_o$ - is time for operate with machine tool (changing cutting modes $n$ and $S$ if it is necessary, cutting tools (generally by revolving of tool holder), fasten moving the cutter close to the processable surface, turn on and turn off feed rate running; $T_m$ – is time for measurements of manufactured part if it does not coincide with direct time.

Generally $T_{aux}$ is determined with the handbook for auxiliary works, for each of them, but sometimes it can be calculated approximately as $T_{aux} \approx 0.15 \cdot T_d$ , min.

Generally **direct** and **auxiliary time** is determined for each technological transition but **time for service** of machine tool and **time for the rest** is determined for whole technological operation.

We calculate direct, auxiliary, service of machine tool, rest, preparation time for each operation and write them in tab. 7.1.

***Operation 1*** (blanked)

***Transition 2*** (cutting off a blank with the length $l$ = 56h16 from a rod having Ø55h16)

The basic time is calculated by the formula (8.4). Generally length of cutting (length in the direction of a feed rate S) is calculated by the formula:

$$L = d_{blank}/2 + l_{uc} + l_{oc} \text{ , mm.} \qquad (7.8)$$

On the basis of the recommendations [7, page 24] is accepted: $l_{uc} + l_{oc}$ = 5 mm.

$$T_d = \frac{L}{n \cdot S_r} = \frac{15+5}{630 \cdot 0.5/2} = 0.15 \text{ min.}$$

The auxiliary time is determined by the formula (8.7):

$$T_{aux} = T_l + T_c + T_o + T_m,$$

where $T_l = 0.12min$ - time for maintaining and fixing (loading) and unloading of a blank [1, tab.5.6, page 199];

$T_c = 0.13min$ - time for clamping of a blank [1, tab.5.7, page 201];

$T_o. = 0.1\ min$ - time for operate (management) of the machine tool [1, tab.5.8, page 202];

$T_m = 0.1\ min$ - time for measurements [1, tab.5.16, page 209].

$$T_{aux} = T_l + T_c + T_o + T_m = 0.12 + 0.13 + 0.1 + 0.1 = 0.45\ min.$$

Operative time is determined by the formula:

$$T_{op} = T_d + T_{awx},\ min. \qquad (7.9)$$

$$T_{op} = T_d + T_{awx}, = 0.15 + 0.45 = 0.6\ min.$$

Time for service of one workplace is determined by the formula:

$$T_s = 0.05 \cdot T_{op} = 0.05 \cdot 0.6 = 0.03 \text{ min.} \qquad (7.10)$$

Time of breaks for rest and personal needs is determined by the formula:

$$T_r = 0.06 \cdot T_{op} = 0.06 \cdot 0.6 = 0.036 \text{ min.} \qquad (7.11)$$

Floor-to-floor time (piece time) is determined by the formula (7.2):

$T_f = T_{op} + T_s + T_r, = 0.6 + 0.03 + 0.036 = 0.666$ min.

Floor-to-floor calculation time is determined by the formula (7.1):

$$T_{fc} = T_f + \frac{T_p}{n_s} = 0.666 + \frac{18}{400} = 0.666 + 0.045 = 0.711 \text{ min}$$

where $T_p$ - preparation time, $T_p$ = 18 min [1, tab. 6.4, page 216]; $n_s$ - quantity of parts in a set, $n_s$ = 400 pieces.

The calculations of the time for different operations are written below.

***Operation 02*** (lathered)

***Transition 2*** (turn off the right end face of a blank with the length $l$ = 52.9h14)
Generally length of cutting is calculated by the formula (7.8):

$$L = d_{blank}/2 + l_{uc} + l_{oc} = 30/2 + 2 + 0 = 17 \text{ mm.}$$

The basic time is calculated by the formula (7.4).

$$T_d = \frac{L}{n \cdot S_r} = \frac{17}{1000 \cdot 0.5/2} = 0.068 \text{ min.},$$

where $S_r$ = 0.5 mmpr - is adjusted feed rate on the gear box, but this feed rate is divided on 2 when we take on the **cross** feed rate; n =1000 rpm (from the previous calculation of cutting speed for the rough turning of the external surface with size 30h11).

The auxiliary time is determined by the formula (7.7):

$$T_{aux} = T_l + T_c + T_o + T_m = 0.12 + 0.13 + 0.1 + 0.2 = 0.55 \ min.$$

where $T_l = 0.12min$ - time for maintaining and fixing (loading) and unloading of a blank [1, tab.5.6, page 199];

$T_c = 0.13min$ - time for clamping of a blank [1, tab.5.7, page 201];

$T_o. = 0.1 \ min$ - time for operate (management) of the machine tool [1, tab.5.8, page 202];

$T_m = 0.2 \ min$ - time for measurements [1, tab.5.16, page 209].

$$T_{aux} = T_l + T_c + T_o + T_m = 0.12 + 0.13 + 0.1 + 0.1 = 0.45 \ min.$$

***Transition 3*** (center hole drilling on the right end face of the blank)

The basic time is calculated by the formula (7.4).

$$T_d = \frac{L}{n \cdot S_r} = \frac{15}{1000 \cdot 0.1} = 0.15 \text{ min.}$$

The auxiliary time is determined by the formula (7.7):

$$T_{aux} = T_l + T_c + T_o + T_m = 0 + 0 + 0.3 + 0 = 0.3 \ min.$$

where $T_l = 0 \ min$ - there is no time for maintaining and fixing (loading) and unloading of a blank (we have taken it into account in the second technological transition);

$T_c = 0 \ min$ - there is no time for clamping of a blank (we have taken it into account in the second technological transition);

$T_o. = 0.3 \ min$ - time for operate (management) of the machine tool: to maintain a center drill, to move the tailstock of a lathe close to the right end face of the blank; to return on the feed rate from 0.5 mmpr to 0.1 mmpr; to turn on the feed rate [1, tab.5.8, page 202];

$T_m = 0 \ min$ - there is no time for measurement (it is need not to measure the length and diameter of center hole because we shall drill the hole with Ø17.5H14.

***Transition 4*** (hole drilling with Ø17.5H14)

The basic time is calculated by the formula (7.4).

$$T_d = \frac{L}{n \cdot S_r} = \frac{52.9 + 0 + 10}{125 \cdot 0.43} = 1.263 \text{ min.}$$

The auxiliary time is determined by the formula (7.7):

$$T_{aux} = T_l + T_c + T_o + T_m = 0 + 0 + 0.3 + 0 = 0.3 \ min.$$

where $T_l = 0$ *min* - there is no time for maintaining and fixing (loading) and unloading of a blank (we have taken it into account in the second technological transition);
$T_c = 0$ *min* - there is no time for clamping of a blank (we have taken it into account in the second technological transition);
$T_o. = 0.3$ *min* - time for operate (management) of the machine tool: to maintain a drill with Ш17.5, to move the tailstock of a lathe close to the right end face of the blank; to return on the feed rate from 0.1 mmpr to 0.43 mmpr; to turn on the feed rate [1, tab.5.8, page 202];
$T_m = 0$ *min* - there is no time for measurement (it is need not to measure the length and diameter of center hole because we shall bore the hole with Ш19.5Н11.

***Transition 5*** (hole boring with Ø19.5H11)

The basic time is calculated by the formula (7.4).

$$T_d = \frac{L}{n \cdot S_r} = \frac{52.9 + 2 + 2}{2000 \cdot 0.21} = 0.133 \text{ min.}$$

The auxiliary time is determined by the formula (7.7):

$$T_{aux} = T_l + T_c + T_o + T_m = 0 + 0 + 0.3 + 0.1 = 0.4 \ min.$$

where $T_o. = 0.3$ *min* - time for operate (management) of the machine tool: to maintain a bore cutter, to move the bore cutter close to the right end face of the blank; to return on the feed rate from 0.43 mmpr to 0.21 mmpr; to adjust on the size Ш19.5Н11; to turn on the feed rate [1, tab.5.8, page 202];
$T_m = 0.1$ *min* - time for measurement [1, tab.5.16, page 209].

***Transition 6*** (boring the chamfer with size $3.5J_s15$ on the right end of the bored hole)

The basic time is calculated by the formula (7.4).

$$T_d = \frac{L}{n \cdot S_r} = \frac{3.5}{2000 \cdot 0.1} = 0.016 \text{ min.}$$

The auxiliary time is determined by the formula (7.7):

$$T_{aux} = T_l + T_c + T_o + T_m = 0 + 0 + 0.1 + 0.1 = 0.2 \ min.$$

where $T_o$. = $0.1$ *min* - time for operate (management) of the machine tool: to move the bore cutter close to the right end face of the blank; it is need not to turn on the feed rate because we do it manually [1, tab.5.8, page 202];
$T_m = 0.1$ *min* - time for measurement [1, tab.5.16, page 209].

Operative time of ***operation 02*** is determined by the formula (7.9):

$$T_{op} = \sum(T_d + T_{awx}) = (0.068 + 0.55) +(0.15 + 0.3) +(1.263 + 0.3) +(0.133 + 0.4)+ +(0.016 + 0.2) = 3.38\ min.$$

Time for service of one workplace is determined by the formula (7.10):

$$T_s = 0.05 \cdot T_{op} = 0.05 \cdot 3.38 = 0.169 \text{ min.}$$

Time of breaks for rest and personal needs is determined by the formula (7.11):

$$T_r = 0.06 \cdot T_{op} = 0.06 \cdot 3.38 = 0.203 \text{ min.}$$

Floor-to-floor time (piece time) is determined by the formula (7.2):
$T_f = T_{op} + T_s + T_r$,= 3.38 + 0.169 + 0.203 = 3.752 min.

Floor-to-floor calculation time is determined by the formula (7.1):

$$T_{fc} = T_f + \frac{T_p}{n_s} = 3.752 + \frac{18}{400} = 3.752 + 0.045 = 3.797 \text{ min}$$

where $T_p$ - preparation time, $T_p$ = 18 min [1, tab. 6.4, page 216]; $n_s$ - quantity of parts in a set, $n_s$ = 400 pieces.
The calculations of the basic time for different operations are written in table 7.1.

Table 7.1. Calculation of laboriousness of shaft manufacturing

| Number | | Modes | | Length L, mm/ dia-meter d, mm | Time, min | | | | $T_{op}$, min | $T_s$, min | $T_r$, min | $T_f$, min | $T_p$, min | $T_{fc}$, min |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Op. | Tr. | n, rpm | S, mmpr | | $T_d$ | $T_i$+ $T_{fast}$ | $T_o$ | $T_m$ | | | | | | |
| ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** | ***8*** | ***9*** | ***10*** | ***11*** | ***12*** | ***13*** | ***14*** | ***15*** |
| | | | | | | | | | | | | | | |
| **01** | 1 | | | | | 0.25 | | | | | | | | |
| | 2 | 630 | 0.21 | 20 | 0.15 | --- | 0.1 | 0.1 | 0.6 | 0.03 | 0.04 | 0.67 | 18 | **0.71** |
| | | | | | | | | | | | | | | |
| | 1 | | | | | 0.25 | | | | | | | | |
| | 2 | 1000 | 0.5/2 | 20 | 0.07 | --- | 0.1 | 0.1 | | | | | | |
| **02** | 3 | 1000 | 0.1 | 15 | 0.15 | --- | 0.3 | 0 | | | | | | |
| | 4 | 125 | 0.43 | 68 | 1.26 | --- | 0.3 | 0 | 3.38 | 0.17 | 0.2 | 3.75 | 18 | **3.8** |
| | 5 | 2000 | 0.21 | 55 | 0.13 | --- | 0.3 | 0.1 | | | | | | |
| | 6 | 2000 | 0.1 | 3.5 | 0.02 | --- | 0.1 | 0.1 | | | | | | |
| | | | | | | | | | | | | | | |
| | 1 | | | | | 0.25 | | | | | | | | |
| | 2 | 1000 | 0.5/2 | 20 | 0.07 | --- | 0.1 | 0.1 | | | | | | |
| **03** | 3 | 1000 | 0.5 | 54 | 0.11 | --- | 0.1 | 0.1 | 1.5 | 0.08 | 0.09 | 1.67 | 18 | **1.72** |
| | 4 | 2000 | 0.11 | 54 | 0.25 | --- | 0.1 | 0.1 | | | | | | |
| | 5 | 2000 | 0.1 | 3.5 | 0.02 | --- | 0.1 | 0.1 | | | | | | |
| | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **04** | 1 | | | | | 0.25 | | | 0.51 | 0.03 | 0.03 | 0.57 | 18 | **0.62** |
| | 2 | 2000 | 0.1 | 11 | 0.06 | --- | 0.1 | 0.1 | | | | | | |
| ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** | ***8*** | ***9*** | ***10*** | ***11*** | ***12*** | ***13*** | ***14*** | ***15*** |
| **05** | 1 | Quenching HRC 50…55 a set of parts (200 pieces) by heating at temperature 850…890ºC during 60 min and then cooling in oil Industrial 40 at temperature 20…30ºC | | | | | | | 0.4 | 0.02 | 0.02 | 0.44 | 30 | **0.**52 |
| | 2 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| **06** | 1 | | | | | 0.25 | | | | | | | | |
| | 2 | $n_{gr}$ = 2350 $n_{part}$= 300 | 12.5; | 80/250 t=0.03 mm; $2 \cdot z_{max}$= 0.221 mm. | 0.02 ×i= 0.02 ×5× 2 = = 0.2 | --- | 0.1 | 0.1 | 0.63 | 0.03 | 0.04 | 0.7 | 30 | **0.78** |
| | | | | | | | | | | | | | | |
| **07** | A1 | | | | | 0.25 | | | | | | | | |
| | 2 | $n_{gr}$ = 2350 | $S_l$ =20 mpm, $S_{cr}$= 0.2·B = 0.2·20 =4 mmpp | 50/250 t=0.03 mm; $2 \cdot z_{max}$= 1.19 mm. | 0.003×10 ×i= 0.03 ×40 = 1.2 | --- | 0.1 | 0.1 | | | | | | |
| | B 3 | | | | | 0.25 | | | | | | | | |
| | 4 | $n_{gr}$ = 2350 | $S_l$ =20 mpm, $S_{cr}$= 0.2·B = 0.2·20 =4 mmpp | 50/250 t=0.03 mm; $2 \cdot z_{max}$= 0.462 mm. | 0.003×10 ×i= 0.03 ×17 = 0.51 | --- | 0.1 | 0.1 | 1.65 + 0.7= 2.35 | 0.12 | 0.14 | 2.61 | 30 | **2.69** |
| | 5 | | | | | 0.25 | | | | | | | | |
| | | | | | | | | | | | | | | |
| **08** | 1 | | | | | 0.25 | | | | | | | | |
| | 2 | $n_{gr}$ = 2350 $n_{part}$= 300 | 12.5; | 80/15 t=0.01 mm; $2 \cdot z_{max}$= 0.521 mm. | 0.02 ×i= 0.02 ×26 ×2 = = 1.04 | --- | 0.1 | 0.1 | 1.49 | 0.08 | 0.09 | 1.66 | 30 | **1.74** |
| | | | | | | | | | | | | | | |
| **09** | | | | | | | 2.5 | | | | | | | **2.5** |
| | | | | | | | | | | | | | | |

**Total calculated floor-to-floor time** of technological process is calculated:

$\sum T_{fc}$ =0.71+3.8+1.72+0.62+0.52+0.78+0.375+2.69+1.74 +2.5=**15.455** min.

# 8. Design Section

The aim is to design a suitable attachment (workholding device) for a mechanical part which we are going to manufacture. We will mill both ends of the shaft, which will be lying in two prisms. The angle of the prisms is 90 degrees. On the scheme is shown the pneumatic attachment of the shaft gripped in prisms.

We have to calculate the required force for our attachment and also the force we will get by pneumatic mechanism. Piston force has to be much higher than required force.

1. **Given and chosen:**

Diameters required for calculations:

$d_1 = \emptyset\, 34h16$

$d_2 = \emptyset\, 24h16$

$d_3 = \emptyset\, 44h16$

Friction: $f_3 = f = 0{,}1$

Feed rate: $S_z = 0{,}09 \ldots 0{,}18 \rightarrow 0{,}1\ \text{mm/tooth}$

Cutting tool life: $T = 150\ \text{min}$

Ultimate strength of machined material (steel 40X): $\sigma_{UTS} = 1000\ \text{MPa}$

Pressure in cylinders of pneumatic mechanism: $p = 0{,}4\ \text{MPa}$

2. **Calculations:**

Diameter of a milling cutter:

$$d_{mill} = 2 * \left(\frac{d_3}{2} + t_1 + t_{safe} + \frac{d_3}{2} + \frac{d_1}{2}\right) = 2\left(\frac{40}{2} + 10 + 10 + \frac{44}{2} + \frac{34}{2}\right) = 158\ mm$$

$$d_{mill} \geq 158\text{mm}$$

We are choosing a milling cutter ГОСТ 5348-69 ø160 mm

| | |
|---|---|
| Hole - | $d = 40$ mm |
| Big diameter - | $D = 160$ mm |
| Width - | $B = 15$ mm |
| Teeth - | $Z = 12$ |
| Material of a mill | T15K6 |

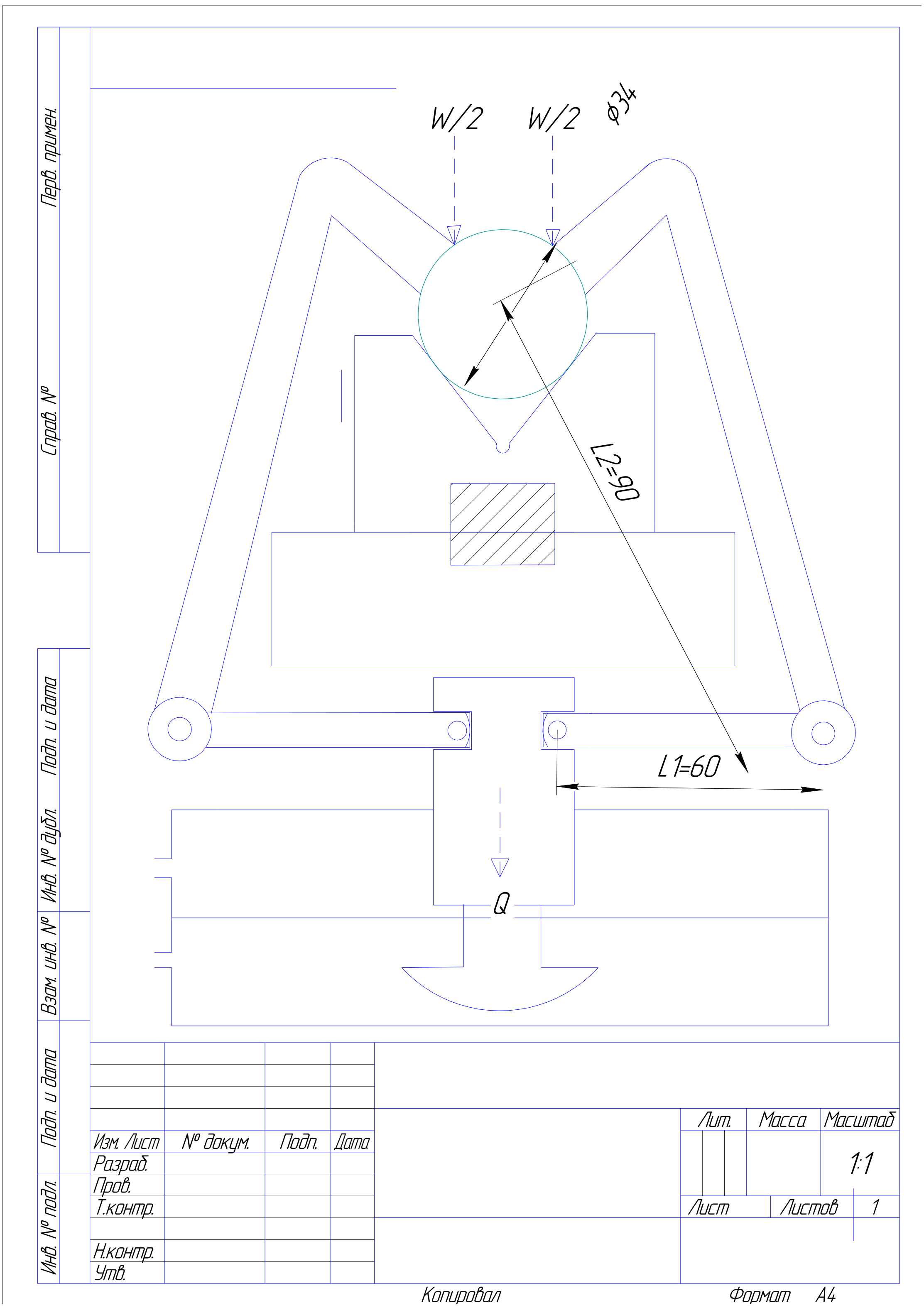



Fig. 8.1. Scheme of piston force calculation

Maximum allowance:

$$Z_{12\,max} = Z_{12min} + T_{A01} + T_{A12} = 0{,}81 + 2{,}9 + 1{,}15 = 4{,}86 \approx 4{,}9\ \text{mm}$$

Cutting speed:

$$v = \frac{c_v * D^{cv}}{T^m * t^x * S_z^y * B^u * Z^p} * K_v = \frac{1340 * 160^{0,2}}{150^{0,35} * 34^{0,4} * 0{,}1^{0,12} * 4{,}9^0 * 12^0} * 0{,}57 = 117\ \text{m/min}$$

$$K_v = K_{mv} * K_{nv} * K_{uv} = 0{,}71 * 0{,}8 * 1 = 0{,}57$$
$$K_{nv} = 0{,}8$$
$$K_{mv} = K_g * \left(\frac{750}{\sigma_{tor}}\right) = 0{,}95 * \left(\frac{750}{1000}\right)^1 = 0{,}71$$
$$K_{uv} = 1$$

Frequency of spindle revolution:

$$n_{calc} = \frac{1000 * v}{\pi * d_{mill}} = \frac{1000 * 117}{\pi * 160} = 212{,}6\ \text{r/min}$$
$$n_{acc} = 200\ \text{r/min}$$

Feed rate of milling cutter:

$$S_m = S_z * Z * n_{ace} = 0{,}1 * 12 * 200 = 240\ \text{mm/min}$$

Force in z axis:

$$P_Z = \frac{10 * c_p * t^x * S_Z^y * B^u * Z}{D^{cv} * n^w} * K_{mp} = \frac{10 * 261 * 34^{0,9} * 0{,}1^{0,8} * 4{,}9^{1,1} * 12}{160^{1,1} * 200^{0,1}} * 1{,}09 = 1615\ \text{N}$$

$$K_{mp} = \left(\frac{\sigma_{tor}}{750}\right)^{np} = \left(\frac{1000}{750}\right)^{0,3} = 1{,}09$$

Gripping force:

$$W = \frac{K * M_{torsiom}}{r\left(f * \sin\frac{\alpha}{2} + f_3\right)} = \frac{2 * 27{,}45}{17\left(0{,}1 * \sin\frac{90}{2} + 0{,}1\right)} = 18{,}9 \approx 20\ \text{N}$$
$$M_{torsion} = P_Z * \frac{d}{2} = 1615 * \frac{34}{2 * 1000} = 27{,}45\ \text{Nm}$$

Torque equation:

$$W * l_2 = Q_{req} * l_1$$
$$Q_{req} = \frac{W * l_2}{l_1} = \frac{20 * 90}{60} = 30\ \mathrm{N}$$

Force of piston:

$$Q_{piston} = \left(\frac{D^2 * \pi}{4} - \frac{d^2 * \pi}{4}\right) * p = \left(\frac{0{,}25^2 * \pi}{4} - \frac{0{,}03^2 * \pi}{4}\right) * 0{,}4 * 10^6 = 19352\ \mathrm{N}$$

$$Q_{piston} \gg Q_{req}$$

**Conclusion:**

We figured out that the force of piston ($Q_{piston}$) which we are going to get is much higher than the required force ($Q_{req}$). Although the piston force is much higher we are not going to change parameters of pneumatic mechanism. The reason is that if there will be some oil the coefficient of friction will dramatically change and required force will be higher. Also our attachment might be used for a harder material that shown in calculations.

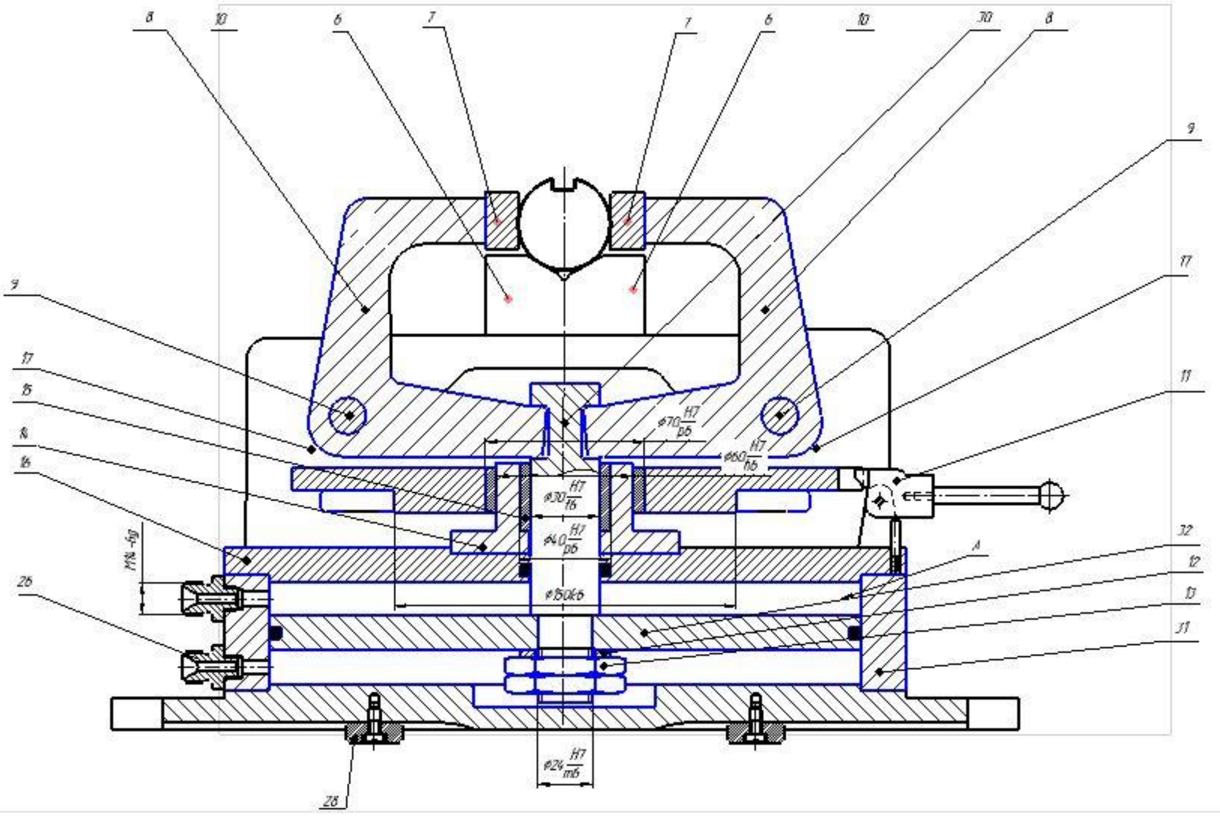


Fig. 8.2. Sketch of workholding device assembly drawing

## 9. Economic section

Technological cost of a part - is the sum of the costs of the implementation process of its manufacturing operations, excluding purchased parts, assemblies. It includes all direct costs associated with the maintenance and operation of process equipment by means of which products are manufactured. Technological cost of - one of the main indicators of technological products.

Technological self-cost machining parts annual production of one denomination is given by:

Amiss = N (ZM + ΣCi), rub.

where N - annual program of the issue, pcs .; = Pc.

ZM - the cost of basic materials, attributable to the item, rub .;

Ci- technology cost of the i-th operation one piece, rub .;

i = 1 ... n - machining operation according to the technological process of manufacturing parts.

(Pub=Rubles)

*Table 9.1*

***Calculation of the guild (technological) cost***

| Expenditure | Justification of the expense | Consumption per unit, *RUB.* |
|---|---|---|
| 1. The cost of basic material | $З_м = Н_м \cdot Ц_{1кг}$ | 11.1 |
| 2. Basic salary basic workers | $З_о = \frac{C_j \cdot t_{шт}}{60}$ | 180.91 |
| 3. Additional salary major job | $З_{доп} = 0{,}1 \cdot З_о$ | 18.09 |
| 4. Depreciation costs equipment | $A = \frac{S_{ст} \cdot H_а \cdot t_{шт}}{Ф_д \cdot 60}$ | 83.41 |
| 5. The costs of current repairs of equipment | $P = \frac{k_р \cdot S_{ст} \cdot t_{шт}}{Ф_д \cdot 60}$ | 29.97 |
| 6. The cost of power electricity | $Э = \frac{W_{ст} \cdot k_м \cdot k_в \cdot Ц_{1квт} \cdot t_{шт}}{60}$ | 9.16 |
| 7. The costs of production space | $F = \frac{F_{ст} \cdot k_{доп} \cdot Ц_{1м} \cdot t_{шт}}{Ф_д \cdot 60}$ | 38.89 |
| 8. The cost of tool wear | $И = \frac{0{,}05 \cdot S_{ст} \cdot t_о}{Ф_д \cdot 60}$ | 45.06 |
| 9. The cost of the fixture | $П = \frac{S_{пр} \cdot (a + в)}{N}$ | 0,0595 |
| Total | *Total* | 416.39 |

**1. The cost of the basic material in detail** determined by the formula:

$$З_м = Н_м \cdot Ц_{1кг}, \text{ rub.}$$

$Н_м$ – the flow rate of the material without deduction of waste, *kg;*
$Ц_{1кг}$ – the price of the material, *rub/кg* .

*Table 9.2*

***The cost of materials***

| Material name | The price of the material per 1 kg, RUB. |
|---|---|
| Structural steel and chrome | 37 |

$З_м = Н_м \cdot Ц_{1кг}$,=0,3*37=11,1 *rub*.

**2. . *Basic salary basic workers*** is determined by the formula:

$$З_о = \frac{\sum C_j \cdot t_{шт}}{60}$$

$$З_{ленто} = \frac{C_{ленто} \cdot t_{шг}}{60} = \frac{100 * 1{,}3 * 11.477}{60} = 24.87 руб$$

$$З_{ток} = \frac{C_{ток} \cdot t_{шг}}{60} = \frac{100 * 2{,}71 * 27.001}{60} = 121.95 \text{ руб}$$

$$З_{све} = \frac{C_{све} \cdot t_{шг}}{60} = \frac{100 * 1{,}3 * 2.27}{60} = 4.9 руб$$

$$З_{внутри-шлиф} = \frac{C_{внутри-шлиф} \cdot t_{шг}}{60} = \frac{100 * 1{,}83 * 4.12}{60} = 12.57 \text{ руб}$$

$$З_{кругл-шлиф} = \frac{C_{кругл-шлиф} \cdot t_{шг}}{60} = \frac{100 * 1{,}83 * 5.451}{60} = 16.62 \text{ руб}$$

where $З_о$ – basic wage of workers, *rub*.;
$C_j$ - the hourly wage rate for the operator of the j-th category *, *руб/ч*;
$t_{шт}$ - норма штучного времени на операцию, *мин*.

*Table 9.3*

***The qualification level of the major job***

| Discharge machinist | 3 | 4 | 5 | 6 |
|---|---|---|---|---|
| Tariff the coefficient | 1,3 | 1,83 | 2,71 | 4,88 |

***1.*** Hourly wage rate machinist 1st class at the current time to calculate by the formula: $C_1 = \frac{MPOT}{22 \cdot 8} =$,

where *MPOT* – the minimum wage at the current time, RUB; 22 – the number of working days per month; 8 – the duration of the working day, including

**2**. We have mass production, the degree of execution of work is low, but the production is dominated by the CNC lathes and a milling machine. Take the category of machine operator 5, then the tariff coefficient = 2,71, and Accept the discharge machinist tariff ratio = 1,3.

**3. *Additional salary major job*** (social insurance) is based on 30% of basic salary:

$$З_{соц} = 0.3 \cdot З_о = 0.3 \cdot 180.91 = 54.27 \text{ руб.}$$

**4. *The depreciation costs of equipment*** are defined by the formula:

$$A = \frac{S_{ст} \cdot H_а \cdot t_{шт}}{Ф_д \cdot 60 \cdot 2} = \frac{2450184 * 0,167 * 49.66}{2030 * 60 * 2} = 83.41 \text{ руб}$$

. where $S_{ст} = 1{,}1 \cdot S_{пер}$ – the carrying value of the equipment (machine) resulting from the original cost of the equipment and delivery costs (transport costs) and installation in the amount of 10% of Sпер;

$Ф_д$ – actual annual Fund operating time of equipment ($Ф_д$ = 2030 during one shift, determining the payback period of the equipment useful life $T_н = \frac{1}{H_a}$ = 6. Uniform norms of depreciation for metal cutting equipment weighing up to 10 tons of mechanical engineering and Metalworking 0,16.

***5. Costs for the current repair of equipment:***

$$P = \frac{к_р \cdot S_{ст} \cdot t_{шт}}{2 \cdot Ф_д \cdot 60} = \frac{0,06 * 2450184 * 49.66}{2030 * 2 * 60} = 29.97 \text{ руб}$$

where $k_p$ = 0,06 – the ratio of maintenance cost of equipment.

*Table 9.4*

The load factor of electric motors in power

| Model of the equipment | Cost on machining, *rub.* | Power, *кWt* | Dimensions, mm |
|---|---|---|---|
| Lathe, Turning Machine DNC, Model НК63 | 350000 | 11 | 3500 * 1580 |
| Turret, turret lathe, broaching | 127440 | 0.45 | 970 *410 |
| Drilling machine 2A135 | 65000 | 4.5 | 1240 * 810 |
| milling machine Model 3К227В | 1000000 | 9 | 2900 * 2080 |
| Circular grinding machine 3140 | 1000000 | 4 | 4480*2200 |

***6. Costs for the current repair of equipment:***

$$Э = \frac{W_{ст} \cdot k_м \cdot k_в \cdot Ц_{1квт} \cdot t_{шт}}{60}, \text{ руб.}$$

where $W_{ст}$ – the motor power of the machine, *кВт*;

$k_м$, $k_в$ – usage of the motor power and time;

$Ц_{1квт}$– the price of electricity in an industrial plant at the current time, *руб/кWt*.

***Cost for electricity :***

$$Э = \frac{W_{ст} \cdot k_{м} \cdot k_{в} \cdot Ц_{1квт} \cdot t_{шт}}{60}, rub.$$

*Table 9.5*

The load factor of motors on time

| Metal cutting machines | The load factor of electric motors time $k_в$ | | |
|---|---|---|---|
| | Type of production | | |
| | Single and small-scale | Medium | Large-scale and mass |
| Boring | 0,4 | 0,5 | 0,6 |
| Drilling | 0,5 | 0,6 | 0,7 |
| Turning, face, carousel, slotting | 0,5 | 0,6 | 0,7 |
| Revolving, turret lathe, broaching | 0,6 | 0,7 | 0,8 |
| Grinding | 0,4 | 0,5 | 0,6 |
| Finishing | 0,4 | 0,5 | 0,6 |
| Cutting, gear cutting, retinoblastoma | 0,6 | 0,7 | 0,8 |
| Milling | 0,6 | 0,7 | 0,8 |
| Semi-automatic machines, machines, aggregate | 0,7 | 0,8 | 0,9 |

$$F = \frac{F_{ст} \cdot k_{доп} \cdot Ц_{1м} \cdot t_{шт}}{Ф_{д} \cdot 60} = руб.$$

Horizontal milling machine model 6P80

$$F = \frac{F_{ст} \cdot k_{доп} \cdot Ц_{1м} \cdot t_{шт}}{Ф_{д} \cdot 60} = руб.$$

Screw - cutting lathe CNC model 16К20Ф3

$$Э = \frac{W_{ст} \cdot k_{м} \cdot k_{в} \cdot Ц_{1квт} \cdot t_{шт}}{60} = \frac{0.45 * 0,7 * 0,7 * 5.257 * 11.477}{60} = 0.22руб$$

Turning or lathe machines ЧПУ Модель НК63

$$Э = \frac{W_{ст} \cdot k_{м} \cdot k_{в} \cdot Ц_{1квт} \cdot t_{шт}}{60} = \frac{11 * 0,7 * 0,4 * 5.257 * 27}{60} = 7.29руб$$

Drilling Machine 2A135

$$Э = \frac{W_{ст} \cdot k_{м} \cdot k_{в} \cdot Ц_{1квт} \cdot t_{шт}}{60} = \frac{4.5 * 0,6 * 0,4 * 5.257 * 2.27}{60} = 0.21 руб$$

Round/circular grinding machine 3140

$$Э = \frac{W_{ст} \cdot k_{м} \cdot k_{в} \cdot Ц_{1квт} \cdot t_{шт}}{60} = \frac{4 * 0,5 * 0,6 * 5.257 * 5.45}{60} = 0.57$$

$Э_{общ} = \sum Э = 9.16$ *руб.*

***7. The costs of production space occupied by equipment:***

$$F = \frac{F_{cm} \cdot k_{доп} \cdot Ц_{1м} \cdot t_{шт}}{Ф_{д} \cdot 60}, rub.$$

where $F_{cm}$– the area occupied by the equipment (machine), $м^2$;

$k_{доп}$ – coefficient taking into account additional space for aisles, driveways ($k_{доп}$ = 2,5 for machines with DNC, $k_{доп}$ = 3 – for the rest);

$Ц_{1м}$ – the rental price of 1 m2 production area per year at the moment, *руб*.

$Ц_{1м}$ *= 7257 руб*

Screw - cutting lathe CNC model 16К20Ф3

Turning machine DNC  Model НК 63

$$F = \frac{F_{ст} \cdot k_{доп} \cdot Ц_{1м} \cdot t_{шт}}{Ф_{д} \cdot 60} = \frac{5,53 * 2,5 * 7527 * 27}{2030 * 60} = 23.07 \text{ руб}$$

Drilling machine 2A135

$$F = \frac{F_{ст} \cdot k_{доп} \cdot Ц_{1м} \cdot t_{шт}}{Ф_{д} \cdot 60} = \frac{1 * 3 * 7527 * 2.27}{2030 * 60} = 0.42 \text{ руб}$$

Round/circular grinding machine 3140

$$F = \frac{F_{ст} \cdot k_{доп} \cdot Ц_{1м} \cdot t_{шт}}{Ф_{д} \cdot 60} = \frac{9.86 * 3 * 7527 * 5.45}{2030 * 60} = 9.96 \text{ руб}$$

$$F_{общ} = \sum F = 38.89 \text{ руб}$$

***8. The cost of the wear of the cutting tool:***

$$И = \frac{(1+0,05) \cdot Ц \cdot t_{o}}{S_{ст}}, \text{руб}$$

*where* $t_o$ – norm normal time for the operation, *мин*.

• Bandsaw blade

Ц – *Price of the cutting instrument rub.*

$S_{ст}$ – *Instrument life, (min)*

- Scoring cutter

$$N = \frac{(1+0,05) \cdot Ц \cdot t_{o}}{S_{ст}} = \frac{1.05 * 280 * 9}{120} = 22.05 \text{руб}$$

- Band saw blade

$$N = \frac{(1+0,05) \cdot Ц \cdot t_{o}}{S_{ст}} = \frac{1,05 * 180 * 0.22}{120} = 0.35 \text{ руб}$$

- Drills

$$N = \frac{(1+0{,}05)\cdot Ц \cdot t_o}{S_{ст}} = \frac{1{,}05 * 550 * 2.32}{120} = 11.12 \text{ руб}$$

- Finish instrument

$$N = \frac{(1+0{,}05)\cdot Ц \cdot t_o}{S_{ст}} = \frac{1{,}05 * 220 * 1.51}{120} = 2.91 \text{ руб}$$

Die cutter

$$N = \frac{(1+0{,}05)\cdot Ц \cdot t_o}{S_{ст}} = \frac{1{,}05 * 230 * 0{,}06}{120} = 0.12 \text{ руб}$$

- The cutter passing
-

$$N = \frac{(1+0{,}05)\cdot Ц \cdot t_o}{S_{ст}} = \frac{1{,}05 * 235 * 0.414}{120} = 0.85 \text{ руб}$$

- Disk cutter

$$N = \frac{(1+0{,}05)\cdot Ц \cdot t_o}{S_{ст}} = \frac{1{,}05 * 2500 * 0.35}{120} = 7.66 \text{ руб}$$

$И_{общ} = \sum И$=45.06 руб.

***9. The cost of the fixture:***

$$П = \frac{S_{пр}\cdot(a+в)}{N} = \frac{850\cdot(0{,}5+0{,}2)}{10000} = 0{,}0595 \text{ руб.}$$

where $S_{пр}$ - the cost of special fixtures, *руб*.;

$a$ = 0,3-0,5 – the depreciation rate;

$в$ = 0,1-0,2 – the ratio of maintenance cost;

$N$ – the annual program, which developed a device, *шт*.

$$П = \frac{S_{пр}\cdot(a+в)}{N} = \text{ руб.}$$

where $S_{пр}$ - the cost of special fixtures, *руб*.;

$a$ = 0,3-0,5 – the depreciation rate;

$в$ = 0,1-0,2 – the ratio of maintenance cost;

$N$ – the annual program, which developed a device, *шт*.

*Table 9.6*

The cost of special fixtures

| Group fixtures | The number of types of parts, pieces. | The cost of fixtures, RUB. |
|---|---|---|
| 1. Small fit (size up to 200×200×200) with a simple case, just to fix the parts (different coasters, simple bars, Cams, etc.) | to 5 | to 850 |
| 2. Small devices (dimensions up to 300×300×300) with buildings of average complexity (collet mandrel, a simple milling fixture, jigs) | 3-5<br>5-10<br>10-15 | 850-1700<br>1700-3000<br>3000-4500 |
| 3. Fixtures with buildings of average complexity (size 400×400×400) with a complex principle of operation (indexing, rotary mechanisms), with simple or medium complexity clamps (gearings) | 10-15<br>15-20<br>20-25 | 3000-3350<br>3350-3600<br>3600-3900 |
| 4. Medium fixture with complex cases (2-3 walls), with a complex medium complexity, principle of operation, with pneumatic actuator | 20-25<br>25-30<br>30-35<br>35-40 | 3900-4150<br>4500-6200<br>6200-6400<br>6400-6900 |
| 5. The average dimensions of the fixture (500×50×500) with complex cases and challenging principle. Major adaptations (over 500×500×500) simple steps with clips medium difficulty | 35-40<br>40-45<br>45-50<br>50-55 | 6900-7350<br>7350-8100<br>8100-9250<br>9250-10000 |
| 6. Large fixture with complex buildings complex principle of action, with complex clamps, pneumatic and hydraulic | 50-55<br>55-60<br>60-65<br>65-75<br>75-90 | 10000-12500<br>12500-14500<br>14500-17500<br>17500-19000<br>19000-21500 |

Production cost:

$$\mathrm{C}_{\text{произв}} = \mathrm{C}_{\text{цех}} + \mathrm{P}_{\text{общез}}$$

wher $\mathrm{C}_{\text{цех}}$ – Shop cost

$\mathrm{P}_{\text{общез}}$ - General factory cost

$C_{цех}$=1,5*$C_{тех}$=1,5*416.39=624.39 руб,

$P_{общез}$=1,8*$C_{тех}$=1,8*416.39=749.50 руб ;

$C_{произв} = C_{цех} + P_{общез}$=624.39+749.50=1373.89 руб.

# 10. SOCIAL RESPONSIBILITY

This section of the thesis is devoted to the analysis and development of measures to ensure favourable for creative work of an engineer-technologist working conditions.

It addresses issues of industrial safety, ergonomics, fire safety and environmental protection.

## Introduction.

Technological progress has made a major change in the conditions of industrial activity of knowledge workers. Their work has become more intensive, intensive, requiring significant investment of mental, emotional and physical energy. This required a comprehensive solution of problems of ergonomics, hygiene and labor organization, regulation of modes of work and rest.

Nowadays computer technology is widely used in all fields of human activity. When working with the computer the person is exposed to a number of dangerous and harmful production factors: electromagnetic fields (frequency range: 5 Hz to 2 kHz, 2 kHz - 400 kHz), ionizing radiation, noise, static electricity, etc. (SanPiN 2.2.2/2.4.1340-03 Sanitary-epidemiological rules and norms "Hygienic requirements for personal electronic computing machines and the organization of work").

Computer work is characterized by significant mental stress and neuron-emotional stress operators, high tension visual work and a big enough load on the muscles of the hands when working with the keyboard of the computer. Of great importance for the rational design and layout of the workplace, which is important to maintain an optimal working posture of the human operator.

### 9.1 Analysis of dangerous and harmful factors.

The production conditions in the workplace are characterized by the presence of some dangerous and harmful factors (GOST 12.0.002-80 "SSBT. Basic concepts. Terms and definitions"), which are classified by groups of elements: physical, chemical, biological and psychophysiological (GOST 12.0.003-74 "SSBT. Dangerous and harmful factors. Classification").

On working at the computer engineer can have a negative affect following dangerous and harmful production factors:

1. Physical: elevated levels of electromagnetic, x-ray, radiation, the lack of natural light, inadequate artificial illumination of the working area, increased brightness, increased contrast, a direct and a reflected bestcost, excessive dust, risk of electric shock, noise from equipment operation.

2. Chemical: increased content in the air of working zone of carbon dioxide.
3. Psychophysical: eyestrain and consideration; intellectual, emotional, and prolonged static loads; the monotony of work; a large amount of information processed per unit time; inefficient organization of the workplace.

9.1.1 Industrial noise.

The noise worsens the conditions causing a harmful effect on the human body. Working in conditions of prolonged noise exposure experience irritability, headaches, dizziness, memory loss, fatigue, loss of appetite, pain in the ears, etc. Such violations in a number of organs and systems of the human body can cause a negative change in emotional state of a person up to stress. Under the influence of the noise reduced concentration, physiological functions are violated, there is fatigue due to increased energy costs and mental stress, deteriorating speech switching. All this reduces the efficiency and the productivity, quality and safety. Prolonged exposure to intense noise [above 80 dBA] at the hearing of the person leads to its partial or total loss.

The main source of noise in the office are fans of the power supply units of the computer. The noise level ranges from 35 to dB. By SanPiN 2.2.2.542-96 in carrying out the basic work on the computer is the sound level at the workplace should not exceed 50 dBA. To reduce noise walls and ceiling of the room where there is a computers that can be lined with sound absorbing materials.

9.1.2 Electromagnetic and ionizing radiation

Most scientists believe that both short and prolonged exposure to all types of radiation from the monitor is not dangerous for the health of the personnel operating the machines. However, comprehensive data on the risk of radiation exposure from the monitors at working with computers does not exist and research in this direction continues.

Valid values for the parameters of non-ionizing electromagnetic radiation from your computer monitor are represented in table. 4.1.

The maximum level of x-ray radiation in the workplace of the operator of the computer usually does not exceed ber/h, and the intensity of ultraviolet and infrared radiation from the screen of the monitor lies within 10…100мВт/м2.

Table 9.1 - Valid values for the parameters of non-ionizing electromagnetic radiation (in accordance with СанПиН 2.2.2/2.4.1340-03)

| Parameters name electricity | | |
|---|---|---|
| Magnetic flux density | in the frequency range 5 Гц - 2 кГц | 250 нТл |
| | in the frequency range 2 кГц - 400 кГц | 25 нТл |
| The electrostatic field | | 15 кВ/м |

To reduce the impact of these types of radiation monitors are recommended for use with low level radiation (MPR-II, TCO-92, TCO-99), install protective screens, and comply with regulated regimes of work and rest.

9.1.3 Electric shock.

To dangerous factors may include the presence in the premises of the large amount of equipment that uses single-phase electric current voltage of 220 V and frequency 50 Hz.[4] the danger of electrocution study relates to the premises without increased risk, because there is no humidity, high temperature, conductive dust and the possibility of simultaneous contact with the ground bonding metal objects and metal equipment housings.

During normal operation of the equipment danger electrocution small, however, possible modes, called emergency, when there is a random electrical connection of parts under voltage with grounded structures.

Defeat by an electric current or by an electric arc may occur in the following cases:

- when touching live parts during repair, PC;

- single-phase (single pole) touch non-insulated from the ground of the person to uninsulated live parts of electrical installations under tension;

- when you touch natcoweb parts under voltage, that is, in the case of insulation failure;

- in contact with the floor and walls, trapped under voltage;

- if possible short circuit in the high voltage units: the power unit, the scanner monitor.

The main measures to ensure electrical safety are:

- isolation (fencing) live parts, eliminating the possibility of accidental contact with them;

- install protective earthing;

- the existence of a common switch;

- timely inspection of technical equipment, insulation.

## 9.2 Ergonomic analysis of the work process.

### 9.2.1 The microclimate.

The parameters of the microclimate can vary within wide limits, while a necessary condition of human life is to maintain constancy of body temperature through thermoregulation, i.e. the body's ability to regulate heat loss to the environment. The principle of normalization of microclimate creation of optimal conditions for heat exchange of human body with the environment.

Computer science is a source of significant heat, which may result in increase of temperature and decrease of relative humidity in the room. In areas where there are computers, should conform to the defined parameters of the microclimate. Sanitary norms SanPiN 2.2.4.548-96, SanPiN 2.2.2/2.4.1340-03 set the values of parameters of microclimate, creating a comfortable environment. These standards are set depending on the time of year, the nature of the labour process and the nature of the workplace (see tab. 4.2).

The volume of the premises occupied by employees of the data center, shall not be less than 19,5 m3/person with the maximum number of concurrent wsmenu. Feed rate of the fresh air into the premises, where the computers are given in table. 9.3.

Table 9.2. The parameters of the microclimate in rooms where computers

| The period of | The microclimate parameter | Value |
|---|---|---|
| Cold | The temperature of the air in the room<br>Relative humidity<br>The speed of air movement | 22…24°C<br>40…60%<br>до 0,1м/с |
| Warm | The temperature of the air in the room<br>Relative humidity<br>The speed of air movement | 23…25°C<br>40…60%<br>0,1…0,2м/с |

Table 9.3 - Regulations for supplying fresh air to the rooms where the computers are located

| Description of room | Volume flow supplied to the premises of fresh air, m3 /per person per hour |
|---|---|
| Volume up to 20 $m^3$ per person<br><br>20...40 $m^3$ per person | Not less than 30<br><br>Not less than 20 |

To ensure comfortable conditions are used as organizational methods (rational organization of work, depending on time of day and year, the alternation of work and rest) and technical equipment (ventilation, air conditioning, heating system).

9.2.2 Lighting.

Properly designed and implemented industrial lighting improves visual work, reduces fatigue, improves productivity, positively affects the production environment, providing a positive psychological impact on employees, increases safety and reduces injuries.

Insufficient lighting causes eye strain, weakens attention, leads to the onset of premature fatigue. Overly bright lighting causes glare, irritation and pain in the eyes. Wrong direction of light in the workplace can create harsh shadows, glare, confusion working. All these reasons can lead to an accident or occupational diseases, hence the importance of a correct calculation of illumination.

There are three types of lighting - natural, artificial and combined (natural and artificial) .

Natural lighting - lighting daylight penetrating through the light apertures in the outer walling of the premises. Natural light is characterized in that it varies widely depending on time of day, time of year, the nature of the field and a number of other factors.

Artificial lighting is used when working in the dark and during the day when you are unable to provide normalized values of the coefficient of natural light (cloudy weather, short daylight hours). Lighting, which is insufficient according to the norms of natural light supplemented with artificial, is called a combined lighting.

Artificial lighting is divided into operating, emergency, evacuation, security. Illumination, in turn, can be shared or combined. Total - lighting in which the lamps are placed in the upper zone of the room evenly or in relation to the location of the equipment. Combo - lighting, which is added to the total local lighting.

According to SP 52.13330.2011 "Natural and artificial lighting. Actualized edition of SNiP 23-05-95" in the premises of the data center you want to apply a combined lighting system.

When carrying high visual accuracy (the smallest size of an object distinguish between 0,3...0,5 mm) the coefficient of natural lighting (KEO) should not be below 1.5% when visual work average precision (smallest size of an object distinguish between 0,5...1,0 mm) KEO should not be below 1.0%. As sources of artificial light typically used fluorescent lamps type LB or DRL, which are combined in pairs in the lamps, which must be placed above the working surfaces evenly .

Requirements for lighting in rooms with computers, the following: when you run the visual works of high precision General illumination shall be LC, and combined - LC; similar requirements when performing work average precision - 200 and LC respectively.

In addition the entire field of view must be lit evenly is a basic hygiene requirement. In other words, the degree of illumination of the room and the brightness of the computer screen should be approximately equal, because the bright light in the area of peripheral vision significantly increases eye strain and, consequently, leads to fatigue.

### 4.2.3 Ergonomic requirements to the workplace

Design of workplaces, equipped with terminals, is among the important problems of ergonomic design in computer science.

Working place and relative location of all of its elements must correspond to the anthropometric, physical and psychological requirements. Of great importance is also the nature of the work. In particular, when workplace design engineer must meet the following basic conditions: optimal placement of equipment that is part of the workplace and sufficient working space that allows you to perform all the necessary movements and displacement.

Ergonomic aspects of design VideoTerminal jobs, in particular, are: the height of the working surface, the size of legroom, location requirements documents in the workplace (availability and sizes stand for documents, varying placement, the distance from the user's eyes to screen, document, keyboard, etc.), characteristics of the work chair, the requirements to the table surface, the adjustability of the elements of the workplace.

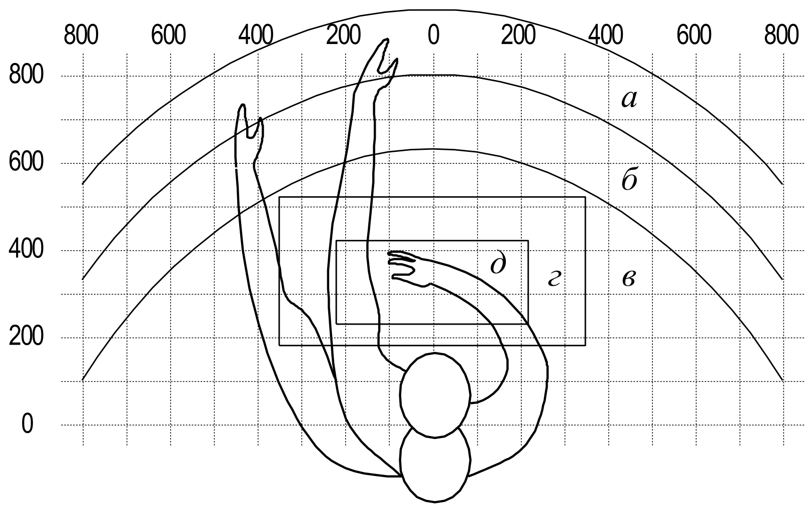
The main elements of the workplace and engineering are the Desk and chair. The main working position is the sitting position.

Working sitting posture causes minimal fatigue engineer. The rational layout of the workplace provides a clear procedure and the permanence of the placement of objects, tools and documentation. What is required to perform work more often located in the zone of easy reach of the workspace.

Motor field - space of the workplace, which can be a physical action of a person.

The maximum range of the hands is a part of the motor field workplace, limited arcs described by the maximally outstretched arms during their movement in the shoulder joint.

The optimal zone is a part of the motor field workplace, limited arcs described by the forearm when moving the elbow with support at the point of the elbow and with relatively immobile shoulder.




a - zone maximum distance;
b - the reach of the fingers at arm's length;
in area easy reach of the hand;
g - optimum space for rough manual work;
d - optimal space for fine Handicrafts.

Fig. 1. Zones of arm in horizontal surface

*Optimal placement of items of work and documentation in the areas of distance:*

The DISPLAY is located in zone a(center);

The SYSTEM UNIT is provided in the recess of the table;

KEYBOARD - in zone g/d;

"MOUSE" - in the area sprawa;

The SCANNER in the zone a/b (left);

The PRINTER is in zone a (right);

DOCUMENTATION: required when working in the area easy reach

palms, and in the drawers of table - literature, constantly unused.

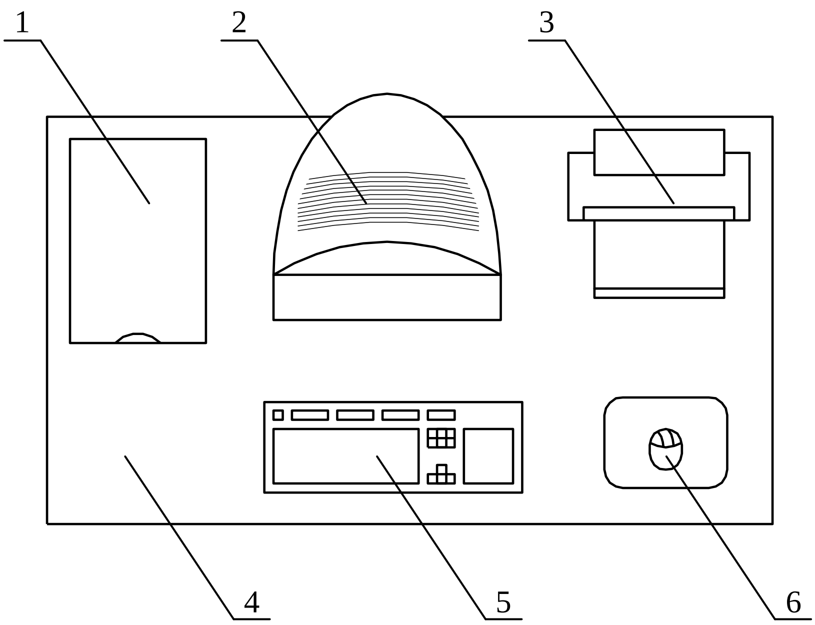



Fig. 2. Personal computer’s components

In Fig. 2 shows an example of placement of the main and peripheral components of a PC on the desktop programmer.
1 scanner, 2 – monitor, 3 – printer 4 – the surface of the desktop,
5 – keyboard 6 – manipulator of type "mouse".
For comfortable work Desk should satisfy the following conditions:
- the height of the table should be selected based on the ability to sit freely in a comfortable pose, if necessary, based on the armrests;
- the lower part of the table needs to be designed to be able to sit comfortably, was not forced to draw in the legs;
- the surface of the table must have the following properties, eliminates glare in the field of view of the programmer;
- the design of the table should have drawers (at least 3 for documentation, listings, stationery).
- the height of the work surface is recommended in the range of 680-760mm. The height of the surface, onto which the keyboard should be about 650mm.

Great importance is attached to the characteristics of the Desk chair. So, recommended seat height above floor level is in the range of 420-550mm. The seat surface is soft, the front edge rounded, and the back angle is adjustable.

It is necessary to include in the design the possibility of posting documents: at the side of the terminal, between the monitor and keyboard, etc. in addition, in cases where the video display is of low quality images, such as visible flicker, the distance from the eye to the screen make more (about 700 mm) than the distance from the eye to the document (300-450mm). Generally with a high quality image on the video display the distance from your eyes to screen, document and keyboard to be equal.

The screen position is determined by:

- reading distance of (0,6...0,7 m);

- angle reading, the viewing direction 20□ below the horizontal toward the center of the screen, and the screen perpendicular to this direction.

Must also be capable of regulating the screen:

- height +3 cm;

- tilt from -10□ to +20□ relative to the vertical;

- in left and right directions.

Of great importance for the correct working posture of the user. When an uncomfortable working position may have pain in the muscles, joints and tendons. The requirements for the operating posture of the user video terminal the following:

- the head should not be tilted more than 20□,

- shoulders should be relaxed,

- elbows - angle of 80□...100□,- forearms and hands in a horizontal position.

The reason for poor posture of users due to the following factors: there is a good stand for documents, the keyboard is too high, and documents - low, no place to put hands and arms, not enough legroom.

In order to overcome these drawbacks provide General advice: better mobile keyboard; must be provided with special devices for adjusting the height of the Desk, keyboard and screen and the palm rest.

Essential for productive and quality work at the computer to have the dimensions of the labels, the density of their placement, contrast ratio and brightness of the characters and background screen. If the distance from the eye of the operator to the display screen is 60...80 cm, the height of the sign shall be not less than 3mm, the optimal ratio of the width and height of the sign is 3:4, and the distance between the marks – 15...20% of their height. The ratio of the brightness of the screen background and characters - from 1:2 to 1:15.

While using the computer, the physicians are advised to install the monitor at a distance of 50-60 cm from the eye. Experts also believe that the upper part of the video display should be at eye level or slightly below. When a person looks straight ahead, his eyes opened wider than when he looks down. Due to this, the area is significantly increased, causing dehydration of the eyes. Besides, if the screen is mounted high and eyes wide open, disturbed function of blinking. This means that the eye does not close completely, not washed by the lacrimal fluid, do not receive sufficient moisture, leading to fatigue.

The creation of favourable working conditions and the right aesthetic design jobs in manufacturing is of great importance both to facilitate and to enhance its attractiveness, positive impact on productivity.

4.3. Development of measures of protection from dangerous and harmful factors

As measures to reduce noise it is possible to propose the following:

1. Veneer ceiling and walls with sound-absorbing material (reduces noise by 6-8 dB);

2. Shielding the workplace (raising of walls, diaphragms);

3. Installation in computer rooms equipment, producing minimal noise;

4. The rational layout of the room.

Protection from noise should be performed in accordance with GOST 12.1.003-83 "Noise. General safety requirements, and sound insulation of enclosures shall meet the requirements of Chapter SNiP 23-03-2003 "Protection against noise. Design standards".

When protection against external radiation arising from work with display, take the following actions:

According to SanPiN 2.2.2/2.4.1340-03 for optimal health and maintaining health during the work shift must be installed regulated breaks – when 8-hour day duration 15 minutes every hour;

1. The display is set so that from the screen to the operator not less than 60-70 cm;

2. Must be used in displays with built-in protective screens.

Electrical safety technical ways and means:

Since all live parts of the computer are isolated, accidental contact with live parts is excluded.

To provide protection from electric shock when touching metal natcoweb parts that may be under stress as a result of damage to the insulation, it is recommended to use protective grounding.

Chassis ground of the computer is provided by summing the grounding conductor to the supply outlets. The grounding resistance of 4 Ω, according to (PUE) for electrical installations with voltage up to 1000 V.

Organizational measures to ensure electrical safety:

The main organizational activity is instruction and training in safe methods of work, as well as a test of knowledge of safety rules and instructions in accordance with the position in relation to the work performed.

When performing unscheduled and scheduled maintenance of computing the following steps:

- Remove computer from network

- Voltage testing

After performing these steps, the repair of faulty equipment.

If the repair is carried out on live parts under voltage, execution of work is carried out by at least two individuals with means of electrical safety.

9.4.1 Fire safety

The fire in the study, can lead to very adverse consequences (loss of valuable information, property damage, loss of life, etc.), it is therefore necessary to identify and eliminate all causes of fire; to develop a plan of measures for the elimination of fire in the building; the plan of evacuation of people from buildings.

The causes of fire can be:

– malfunction wiring, sockets and switches which may cause a short circuit or breakdown of insulation;

– damaged (defective) electrical appliances;

– use indoor electric heaters with open heating elements;

– the occurrence of a fire due to a lightning strike to the building;

– fire building due to external influences;

– careless handling of fire or non-observance of fire safety.

9.4.2 Prevention of fire

Fire prevention is a complex of organizational and technical measures aimed at ensuring the safety of people on the prevention of fire, limiting its distribution and also creation of conditions for successful fire extinguishing. For the prevention of fire is extremely important proper fire risk assessment of buildings, identification of hazards and justification of the ways and means of parareptilia and protection.

In modern computers a very high density of elements of electronic circuits. In close proximity to each other are arranged to the connecting cord, patch cords. When flowing over them electric current is allocated a significant amount of heat, which may result in raising the temperature to 80-100°C, it is possible to melt the insulation of the connecting wires, their exposure, and, as a result, a short circuit.

For removal of excess heat from computers serve as ventilation and air conditioning. However, they can be an additional fire hazard to the building if the fire spread.

The premise computing laboratory for explosion safety concerns to the category (in accordance with the Federal law from July, 22nd, 2008 N 123-FZ "Technical regulations on fire safety requirements").

One of the conditions of fire safety - the elimination of possible ignition sources. In the office of the ignition sources can be:

– faulty electrical faults in wiring, electrical outlets and switches. To eliminate the risk of fire for these reasons, it is necessary to identify and eliminate defects, carry out routine inspection and eliminate all faults;

– faulty electrical appliances. Necessary measures to prevent fire include the timely repair of electrical appliances, high-quality correction of damage that do not use faulty electrical appliances;

– space heating electric heaters with open heating elements. Open heating surface can cause a fire, as in the room are paper documents and reference materials in the form of books, manuals, and paper – flammable object. In order to prevent fire, do not use outdoor heaters indoors;

– short circuit in the wiring. In order to reduce the probability of fire due to short circuit it is necessary that the wiring was hidden.

– getting into the building from lightning. In the summer during a thunderstorm, possibly a lightning strike resulting in possible fire. To avoid this, it is recommended to install on the roof of the lightning arrester;

– non-observance of measures of fire safety and Smoking indoors can also lead to fire. To eliminate the ignition as a result of Smoking indoors is recommended to strictly forbid Smoking, and allow only in strictly designated place.

In order to prevent fire hold with engineers working in the room, fire drill, which is to familiarize employees with fire safety rules, and to teach the use of primary fire extinguishing means.

In the event of a fire you must first disconnect the power, to call the fire Department, evacuate people from the premises in accordance with the evacuation plan and proceed to extinguish the fire with fire extinguishers. If there is a small hearth fire, you can use the means at hand for the purpose of preventing access of air to the object of fire.

In the laboratory are the primary means of fire suppression, a box of dry sand, water, asbestos blankets, manual powder extinguisher OP - 4. To prevent fire and fire prevention systematically conducted inspection of electrical circuits and equipment are detected early and eliminated the fault. The laboratory has developed an evacuation plan, which made available to the laboratory staff.

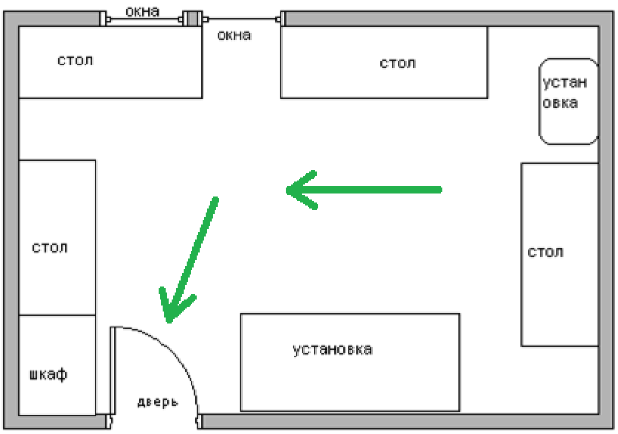



Fig. 3. The evacuation plan

9.5 Environmental Protection

Environmental protection is really important and meaningful process. That is why these issues are devoting a lot of time and attention. Environment is the complex of measures aimed at preventing the negative impact of human activity on nature, providing a favorable and safe conditions of human life.

Creation of conditions for improvement of ecological conditions - the process is long, requires coherence and consistency of action. Priority in the environmental policy of the Russian Federation today the following questions:

- ensuring environmentally safe living conditions;

- rational use and protection of natural resources;

- ensuring environmental and radiation safety (MPE);

- the greening of industry;

- increase of ecological culture of society and the formation of ecological consciousness in humans.

Important role in the protection of the environment is given to the procedures for the rational placement of the sources of contaminants. These include:

1) making industrial enterprises of major cities and new construction in sparsely populated areas with unsuitable and unsuitable for agricultural use of land;

2) the optimum location of industrial enterprises taking into account the topography of the terrain and the wind rose;

3) establishment of sanitary protection zones around industrial plants.

4) the rational layout of the urban area, providing optimal environmental conditions for humans and plants.

In the environment play an important role in the quality of the environment designed to conduct systematic monitoring of the condition of the atmosphere, water and soil for the actual levels of pollution. The information obtained about the dirt allows you to quickly identify the causes of increasing concentrations of harmful substances in the environment and actively to fix them.

Environmental protection is a complex problem that requires the efforts of scientists of many specialties. Of particular importance is the quantitative assessment of the impact of environmental pollution and, above all, damage to the national economy of pollution. Protecting the environment from contamination at the present stage in addition to economic objectives: increasing social productivity - and also includes socio-economic task of improving the conditions of human life, the preservation of his health.

To minimize the level of pollution emitted by the enterprises, it is necessary to make the following mandatory measures for the environmental protection (EP). Measures for environmental protection are:

1. The identification, assessment, permanent control and limitation of harmful emissions into the environment, creating environmental and resource-saving technologies and equipment.

2. The development of legal laws, legal acts on protection of the natural environment, as well as material incentives for compliance with these laws and environmental measures.

3. The prevention of environmental degradation and the environment from harmful and hazardous factors through the creation of dedicated areas (SPZ).

Non-waste technology is the most active form of protection of the environment from the harmful effects of industrial emissions. Under the concept of "soft technology" is understood as the set of activities in production processes from raw materials to ready-made products, thereby reducing to a minimum the amount of harmful emissions and reduces the impact of waste on the environment to an acceptable level. In this set of activities includes:

1) creation and implementation of new processes for products with the formation of the least amount of waste;

2) development of various types of closed technological systems and water cycles on the basis of methods of wastewater treatment;

3) development of systems for recycling of production waste into secondary materials;

4) creation of territorial-industrial complexes having a loop structure material flows of raw materials and waste inside the complex.

Until full implementation of non-waste technology important areas of greening of industrial production should be considered:

1) improvement of technological processes and development of new equipment with lower emissions of pollutants and waste into the environment;

2) the replacement of toxic waste on non-toxic;

3) replacement of non-recyclable waste recyclable;

4) the use of passive methods of environmental protection.

Passive methods of protection of the environment includes a complex of measures to limit emissions from industrial production and subsequent recovery or disposal of waste. These include:

- treatment of wastewater from impurities;

- treatment of gaseous emissions of harmful impurities;

- the dispersion of harmful emissions into the atmosphere;

- suppress noise in its distribution;

- measures to reduce levels of infrasound, ultrasound and vibration in their ways of spreading;

shielding energy sources of environmental pollution.

Enterprises, individual buildings and facilities production processes that are sources of negative impact on the environment and human health, should be separated from residential buildings sanitary-protective zones.

Sanitary protection zone (SPZ) separates the territory of the industrial area from residential buildings, the landscape and recreational areas, recreation areas, resort to compulsory designation of boundaries of the special information signs

Install the following sizes of sanitary protection zones:

- the enterprise of the fourth class - 100 m (Machine-building enterprise with Metalworking, painting without casting.).

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